Influence of Trust in Ambient Assisted Living Technologies

DISSERTATION

submitted in fulfillment of the requirements for the degree of
doctor rerum naturalium (Dr. rer. nat.) in psychology
at Faculty of Life Sciences, Humboldt University Berlin

by

Dipl.-Kaufm. Frederick Steinke

President of Humboldt University Berlin:
Prof. Dr. Jan-Hendrik Olbertz

Dean of Faculty of Life Sciences:
Prof. Dr. Richard Lucius

Advisors:

1. Prof. Dr. Denis Gerstorf (Humboldt University Berlin)
2. Prof. Dr. Claudia Linnhoff-Popien (Ludwig-Maximilians-University Munich)
3. Prof. Dr. Hartmut Wandke (Humboldt University Berlin)

Date of submission: 15.08.2014

Date of disputation: 27.02.2015

TABLE OF CONTENTS

LIST OF FIGURES

ABBREVATIONS

AAL	Ambient Assisted Living
IU	Intention to use
PEOU	Perceived ease of use
PU	Perceived usefulness
SMILEY	Smart and Independent Living for the Elderly
T_{AAL}	Trust in Ambient Assisted Living
TAM	Technology Acceptance Model

ABSTRACT

Interpersonal trust as “expectancy that the verbal statements of others can be relied upon” (Rotter, 1967; p. 651) plays an important role in human relationships. But even in the context of automation and man-machine systems, the consideration of trust has acquired even greater importance in recent years. In the field of automated vehicle control systems or military friend-or-foe recognition, a large number of surveys relating to trust have been conducted. An area of research that, to date, has not been well-investigated is home automation, such as smart home and assistive technologies for older people. The present thesis aims to initiate such research activities in the context of trust in Ambient Assisted Living (AAL) systems, as well as to demonstrate the opportunities that assistive technologies present for impaired persons in the living environment. The focus of the present survey is on the trust of older people, as potential end-users, in AAL systems. To establish an understanding of the state of this research field, a literature review has been conducted. Subsequently, the various factors influencing trust in AAL and usage intention of the elderly target group are examined via a written questionnaire study. Taking into account the variables of the Technology Acceptance Model (TAM) (Davis, 1989), persons with and without need for daily support are interviewed. Based on the obtained results, two subsequent experiments were carried out. The participants in the two experiments, each including a senior test group and a young control group, worked on various tasks through a mock-up on a tablet-computer in the living environment. In the first experiment, in addition to the standard user interface of the AAL technology, either personal support via operator or a technical embedded support was provided to test the differential impact on the trust of the participants in AAL. The second experiment included three different levels of reliability of an AAL application.

Keywords: Ambient Assisted Living (AAL), Older People, Human Factors, Human-Machine-Interaction, Assistive Technology, Trust

ZUSAMMENFASSUNG

Zwischenmenschliches Vertrauen spielt in Beziehungen eine wichtige Rolle und beinhaltet die Erwartung, dass auf das Wort des Anderen Verlass ist (Rotter, 1967). Auch im Zusammenhang mit Automation und Mensch-Maschine-Systemen erlangt die Betrachtung von Vertrauen in den vergangenen Jahren immer größere Bedeutung. In den Bereichen automatisierte Fahrzeugsteuerung oder militärische Freund-Feind-Erkennung wurde bereits eine Vielzahl von Erhebungen durchgeführt. Einen Forschungsgegenstand, der bislang jedoch weitestgehend unbeachtet geblieben ist, stellen Heim-Automatisierungen und Unterstützungstechnologien für ältere Personen dar. Die vorliegende Dissertation möchte einen Anstoß für die Forschungsaktivitäten im Kontext von Vertrauen in Ambient Assisted Living (AAL) Systeme geben und gleichzeitig die Möglichkeiten von Unterstützungstechnologien (für beeinträchtigte Personen) im Wohnumfeld aufzeigen. Im Fokus der Untersuchung steht dabei das Vertrauen älterer Personen, als potentielle Endnutzer, in AAL Systeme. Nach Durchführung der Literaturanalyse, wurden mittels einer Fragebogenstudie zunächst verschiedene Einflussfaktoren auf das Vertrauen in AAL sowie die Nutzungsabsicht der senioren Zielgruppe erforscht. Unter Einbeziehung der Variablen des Technology Acceptance Modells (TAM) (Davis, 1989) werden Personen mit und ohne täglichem Unterstützungsbedarf befragt. Basierend auf den dadurch gewonnenen Erkenntnissen wurden zwei Experimente durchgeführt. Die Probanden der beiden Experimente, die jeweils eine seniore Testgruppe und eine junge Kontrollgruppe umfassten, sollten mittels eines Mock-Ups auf einem Tablet-Computer verschiedene Aufgaben im Wohnumfeld bearbeiten. Im ersten Experiment wurde zusätzlich zu der Standard-Bedienoberfläche der AAL Technologie, entweder persönliche Unterstützung via Operateur oder eine technische Unterstützung zur Verfügung gestellt. Das zweite Experiment untersuchte drei unterschiedliche Stufen von Zuverlässigkeit einer AAL Applikation.

Schlagwörter: Ambient Assisted Living (AAL), Ältere Personen, Human Factors, Mensch-Maschine-Interaktion, Unterstützungstechnologie, Vertrauen

1. INTRODUCTION

The combination of an aging society and the progress of digitization offer both opportunities and risks related to new technology. These technologies should meet the requirements of people who have lived without smart phones, tablet computers and the internet for decades. In particular, in order to be useful, new functionalities should offer a noticeable added value for older people in everyday life. Due to the growing demand for health services, which are especially needed for the elderly, increasing health care expenditures are anticipated (Bundesministerium des Innern, 2011). The lack of qualified caregivers and decrease in family care (Geiger, 2009) present an opportunity to use assistive technology in the residential environment. Technical support via comfort functions, such as regulating the temperature in the apartment or operating lights, has been offered by various vendors in Germany in previous years. By adding more sensors that can measure physiological status (e.g. vital functions such as blood pressure, or automatically alerting the emergency doctor in the event of a fall), AAL systems can provide additional security for people with health problems or physical impairments. With the exception of the control element, other AAL components and services are often intangible or function only in the background. Thus, these components could be difficult to understand for the end-user. The research project *Smart and Independent Living for the Elderly (SMILEY)* pursued the goal of an overall AAL working system that included five modules: my apartment; my reminder; my environment; my health; and my contacts (Fraunhofer ISST, 2013). By means of various requirement analyses, personal interviews, and summative evaluation, a user interface was developed to enable an easily usable design for the surface. Moreover, the functions and services that are identified as most useful for the target group of elderly people are integrated in the SMILEY prototype. This holistic AAL approach serves as the basis for the present thesis.

Because AAL working systems can be responsible for individuals' health, apprehension of users may be anticipated. To mitigate this concern, gaining the trust of older people in this technology can be crucial for its purchase and actual usage. To support the establishment of AAL technology in the market, detailed research with the appropriate target group could be helpful. Consequently, the present thesis provides a comprehensive study to investigate the factors required for the trust of older people to be established for AAL technology. Within the

research environment, the thesis fits into the interface of assistive technology for older people, trust in automation, and the TAM. Figure 1 visualizes the research landscape.

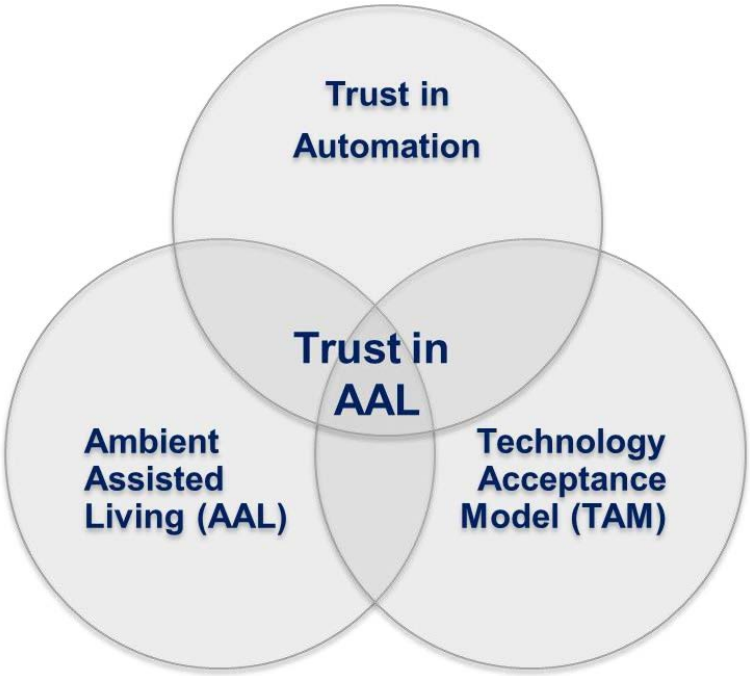


Figure 1. Classification of the research landscape of the thesis

Analyzing the trust of older people in AAL technology offers the chance to acquire a better understanding of the requirements of end-users for this innovative technology. To gain insight into the research that has been performed concerning of trust and human-machine interactions, a literature review was conducted. The analysis of Steinke, Fritsch and Silbermann (2012a) revealed existing trust research in the following seven sub-domains: automotive; aviation; combat identification; healthcare and assistance systems; human-machine interaction; supervisory control systems; and others. The niche "trust in AAL" was not addressed in scientific research (for details see *article 1*; Steinke et al. 2012a).

Due to this lack of previous research addressing trust and AAL, previous studies in trust in other forms of automation are used as the basis for trust research in AAL in this thesis. Muir (1987) noticed that "the importance of trust as a moderator between the properties of a machine and a human's use of that machine suggests that a formal model of trust between humans and machines would be of great value to the designers of human-machine systems in general, and decision aids in particular" (Muir, 1987, p.538). Based on this knowledge, Lee and Moray (1992) conducted the first experiment regarding trust in human-machine systems

and analyzed the connection between trust and changes in operators' control strategies. Also, the connection between different types of trust has been addressed in research. Madhavan and Wiegmann (2007) set up a theoretical framework that described the differences between trust in human–automation and human–human interactions.

In addition to the existing trust research, the TAM (Davis, 1989) will be used as a theoretical approach. Based on the Theory of Reasoned Action (TRA) by Fishbein and Ajzen (1975), the TAM specifies the two most important determinants of user acceptance, perceived usefulness and perceived ease of use (Davis, 1989). Moreover, the attitude toward usage affects the behavioral intention to use, which leads to actual usage. The TAM has been applied and modified in different application fields (see Venkatesh and Davis, 2000; Hu, Chau, Liu Sheng, Yan Tam, 2012; Chen and Chan, 2014). Hu and colleagues (2012) investigated the applicability of the TAM in explaining physicians' decisions to accept telemedicine technology in a health care context. Furthermore, Chen and Chan (2014) developed the senior technology acceptance model (STAM) by integrating variables including cognitive ability and gerontechnology anxiety. In the present thesis, variables from the origin TAM (Davis, 1989) as well as other influencing factors from research on trust in automation will be integrated in the questionnaire development for investigating trust in AAL (see *article 2*; Steinke, Bading, Fritsch and Simonsen, 2014).

The present work includes the following background component in which the demographic development and impact for the German health system is emphasized. Based on this, the need for assistive technology to support people in the home environment is presented, and the importance of trust in automation, and especially AAL, is described. Based on three research questions, the common thread of the thesis is presented. In the methodology section, the relationship between the four integrated studies is explained, and further details on the research structure are provided. The results section presents the research questions and structures the findings before discussing these in general in the discussion section. The thesis ends with a conclusion followed by a short overview about further research activities that should be conducted to broaden the conclusions presented herein.

2. BACKGROUND

The following section begins with a quantitative overview of the demographic shift, with a focus on Germany. The resulting implications for the German health care market will be presented briefly, and will be followed by an introduction to the topics of home automation as well as AAL. Additionally, a description of the construct "trust in automation" and an explanation about the importance of trust in AAL will be presented. To present a better visualization of the connections in the presented research topic, the background section runs as seen in Figure 2.

Figure 2. Structuring of the background section

The need for research in the area of AAL technology derives from the worldwide demographic shift. A growth from 784 million people who are older than 60 years in 2011 to two billion people in 2050 is predicted (United Nations, 2013). In the European Union, Germany has the highest percentage rate (21%) of persons aged 65 years and older (Statistisches Bundesamt, 2012a). The predictions for 2030 imply that 29% of the population - 22 million people - will be aged 65 or over in Germany (Statistisches Bundesamt, 2011). Assuming a simultaneous decrease of the total population, the proportion of the working population is also changing, which negatively influences the German health system. Increasing health care expenditures are anticipated due to the growing demand for health services, which are especially needed for the elderly (Bundesministerium des Innern, 2011). Moreover, an increase in long-term care is predicted, considering the aging population. Staying as long as possible in the familiar home environment is the preferred alternative of people who need care. In 2007, 5% of individuals between 70 and 74 years and 62% of

persons 90 years and older were in need of care. The persons concerned prefer assistance by outpatient services in their own surrounding, in order to delay or avoid a movement to a residential care facility. In 2007, 68% of the persons who required care were assisted at home (Statistische Ämter des Bundes und der Länder, 2010). For older people who are restricted in their mobility due to physical and mental impairments or diseases, their environment is often reduced to their home and their direct neighborhood (Backes and Clemens, 2008). Thus, the need for an age-designed home environment is growing. Additionally to modifications for a barrier-free home environment, new technologies such as AAL have been designed for the requirements of older people to support the personal independence in aging.

The origin of supportive technology in the home environment goes back to the early 1970's. Older persons used a self-organized network via telephone to monitor each other. In case that one member did not respond to the call of the "phone-chain," relatives or professionals would be informed (Paulus, Hilbert and Potratz, 2009). In the following decades, various developments in the context of home automations were achieved. Ambient Intelligence (AmI) was presented in the late 1990s by the 'Information Society Technologies Advisory Group' (ISTAG) in a European research program and described a living environment that is equipped with networked devices that are able to complete diverse functions. This network collects and analyzes data and guides actions independently (Weyrich, 1999). In the further evolutionary step, AAL was developed "as *use of AmI in everyday life. Assisted means assistance, by technical devices as well as by technical or human services*" (Giesecke, Hull, Schmidt, Strese, Weiß and Baumgarten 2005, p. 44). AAL offers a wide range of assistance options for elderly or impaired persons in the market segments of *Health & Homecare*, *Safety & Privacy, Supply & Household as well as Social Environment* (Bundesministerium für Bildung und Forschung, 2008). These solutions are not only focused on quality of life regarding the living area, but extended to all areas of life. "*AAL refers to intelligent systems of assistance for a better, healthier and safer life in the preferred living environment and covers concepts, products and services that interlink and improve new technologies and the social environment*" (Van den Broek, Cavallo and Wehmann, 2010, p. 6). Various sponsored research projects, within the several market segments as well as overlapping in Germany and Europe-wide, have been conducted in the last decade (Bundesministerium für Bildung und Forschung, 2009; Ambient Assisted Living Joint Programme, 2013). For an overview of the widely-ranging technical implementations in the context of AAL, some excerpts should be mentioned. The spectrum of

AAL has included, for example, the maintenance and improvement of social relationships via tablet computer, smartphone, television or social media solutions (Ambient Assisted Living Joint Programme, 2013, for example Hellman, 2012; Nikolaos, 2014; University Duisburg-Essen, 2013) as well as the development of algorithms for the detection of falls in the living environment by the use of biologically-inspired stereo vision sensors, for example as part of the project "CARE" (Belbachir et al., 2012).

AAL technology represents a diversified form of automation in which people are often not directly involved in the decision-making process. In this characteristic, AAL differs from human-machine interaction in other segments of development. The impact of AAL on human performance depends on the type and degree of automation and on the form of assistance. Automation and assistance likewise have influence on the mental workload and attention of the user. Consequences may be over-reliance on automation and reduction of the abilities of the individual (Parasuraman and Riley 1997). As emphasized by Wandke (2005), users "*will not use the technical system or they will use it rudimentarily, ineffectively and inefficiently*" (Wandke 2005, p. 133) when they do not understand or cannot use the functions of the technology or the overall system. Since most of the AAL prototypes that are developed via governmentally-funded research projects are currently not transferred into marketable solutions, field research in AAL is often difficult. The usage characteristics and the understanding of new technologies by users have not been able to be studied with large sample sizes. Research of the intended as well as the actual usage of these products could be helpful for an optimization and adjustment to older persons' requirements.

Since in innovative technologies such as AAL, the complexity has been increasing and is hardly manageable from an end-user perspective, human-machine trust (Muir, 1987) is gaining more importance. As seen in the description of AAL, the degree of automation and assistance (for example in case of detection of falls in the living environment) is high. Trust of a person in a technology or a device, so-called trust in automation, could help to reduce the complexity and uncertainty in case that products or processes are not clear and understandable (Lee and See, 2004). Despite the long-standing development of home automation and efforts to design operable AAL technology, there is almost no research on human behavior associated with these technologies. Studies on trust, acceptance or usage intention, as well as business model analysis, are under-represented in the technical literature. As seen in Steinke and colleagues (2012a), the importance of trust for AAL has, to date, not

been analyzed, which establishes the basis for the present thesis. In contrast, other areas of technology have a long tradition in researching the relationship between automated systems and trust; these will be introduced briefly. A detailed overview can be found in *article 1* (Steinke et al., 2012a).

The 'Turing Effect' initiated the discussion about human trust in information provided by automation compared with another human (Turing, 1950). According to the construct "trust in automation", *"[t]rust can be defined as the attitude that an agent will help achieve an individual's goals in a situation characterized by uncertainty and vulnerability"* (Lee and See, 2004; p. 51). The agent can be characterized as person or automation, which interacts with the person's surrounding. People tend to rely on automation they trust in, and reject automation they do not trust (Muir and Moray 1996). Additionally, the calibration of trust plays an important role in the use of automation (Lee and See, 2004). As seen in Lee and Moray (1992, 1994), usage is positively influenced by individuals' trust in automation. Individual differences in personality and perception can affect the connection between properties of a machine and end-users' trust (Merritt and Ilgen, 2008). Further studies revealed connections between self-confidence (for example Lee and Moray, 1992; 1994; Lewandowsky, Mundy and Tan, 2000), mood (Merritt, 2011), or implicit attitudes toward automation (Merritt, Heimbaugh, LaChapell and Lee 2013) and trust. Moreover, rejection of technology, improper use of the automation, or overreliance can occur in cases when the user is not aware of the real performance of the system (Parasuraman and Riley, 1997; Singh, Molloy and Parasuraman, 1993). As seen in Parasuraman and Miller (2004), overreliance can lead to dangerous situations. An example from the shipping industry shows that, due to a lack of GPS signals on the Royal Majesty and the associated change of the autopilot, one ship sailed into dangerously shallow water zones. As a consequence, $7 million in losses resulted due to damage suffered by the ship and lost revenues. Luckily, nobody was harmed. Unfortunately, inadequate trust in technology does not always yield good results. In air traffic, a tragic accident with 71 dead passengers was caused by distrust in the Traffic Collision and Alerting System (TCAS) and overreliance on human judgments (National Transportation Safety Board, 1997).

In the context of AAL technology, overreliance on technology may also lead to tragedy, in the case that the assistance system does not work correctly (for example due to a defective sensor). In the example of a fall, various stations within the emergency call cascade offer

potential risks for technical or human errors. Between the alarm by the sensor in the home environment, which informs the 24/7 telephone service provider, and the arrival of the emergency doctor who provides first aid, this process may ideally take only a few minutes. As seen in Merritt and colleagues (2013), end-user trust differs on the basis of different system characteristics. Heydenbluth (2013) examined four system characteristics of an AAL emergency application: dependency of fall sensors; alarm transmission via wireless network; mode of operation in the emergency call center; and position detection. The results showed that the AAL system function, including a human component (mode of operation in the emergency call center) was regarded as more reliable in contrast to the other functions. Overall, the 273 participants with mean age 26.2 years (SD = 5.84 years) reviewed the expected reliability of the AAL application as lower than an online cloud service that was analyzed as a second technology (Heydenbluth, 2013). Contrary to these findings, a study by Steinke, Fritsch, Hertzer, Tautz, and Zickwolf (2013) with 206 participants (mean age 38.0 years; SD= 17 years) revealed that the expected reliability for an AAL solution was higher than for other everyday technologies. As seen, for example, in an experiment with a visual detection task, the reliability of automation can strongly influence whether or not individuals will trust the technology (Dzindolet, Pierce, Beck and Dawe, 2002). Moreover, the differentiation between perfect reliability and imperfect automation was discussed in various studies (e.g. Ezer, Fisk and Rogers, 2008; Neyedli, Wang, Jamieson and Hollands, 2010). Since actual reliability is important for the success of an AAL technology, the relationship between trust and reliability will be analyzed in detail in *article 4* (Steinke, Hertzer and Fritsch, 2014), in which the actual reliability of an AAL application is manipulated in an experimental setting.

Considering that during the usage of the AAL system, the perception could be different among multiple user groups (e.g. end users, relatives, health care providers), the complexity increases in the analysis of trust. Montague, Winchester and Kleiner (2010) underlined that "*users with different perspectives of the system have different criteria for developing trust in medical technologies"* (Montague et al. 2010, p. 541). The present thesis concentrates on one of these user groups and places the end user into the focus of attention. The next section presents the three research questions that provide the framework for the thesis.

3. RESEARCH QUESTIONS

The following three research questions are used to structure the overall topic and to concentrate on presenting the main findings. This thesis is not intended to supply a complete answer to these three questions. By means of the first research question, the state of the art was determined. For this purpose, the first research question is:

1) *What is the current state of research in the interplay between trust and Ambient Assisted Living (AAL)?*

This question is mainly answered by the results of the literature review performed for this thesis, in which studies until January 2011 were considered (see *article 1*; Steinke et al., 2012a) and moreover, this question is partly addressed in the previous background section. Before starting the design of the questionnaire survey, it was necessary to analyze the research landscape via standardized online database search. The evaluation of the literature review, which was quantitative as well as qualitative, by clustering the content of the identified studies of interest, demonstrated the need for research in our selected topic. In addition, influencing factors that affect end-users' trust need to be analyzed. Various factors include ease of use (Lee and See, 2004; McGuirl and Sarter, 2006), system reliability (Bailey and Scerbo, 2007; Dixon and Wickens, 2006), workload (Ho, Wheatley and Scialfa, 2005), self-confidence (de Vries, Midden and Bouwhuis, 2003; Gao, Lee and Zhang, 2006; Moray, Inagaki and Itoh, 2000), or mood (Merritt, 2011) have an impact on trust in automation. For the questionnaire survey (see *article 2*; Steinke et al., 2014) and both experiments (see *article 3*; Steinke et al., 2014, and *article 4*; Steinke et al., 2014), selected variables are used for the investigation of trust and intention to use with respect to AAL. The second research question is posed as follows:

2) *Which influencing factors affect end-users' trust in AAL and intention to use?*

Intention to use as a variable is adapted from the TAM variable 'behavioral intention to use' and is upstream to (i.e. it precedes) the actual system use (Davis, 1989; Ma and Liu, 2004). In this thesis, the intended usage of AAL technology is measured via questionnaire and is not equal to the actual use by an end-user. The multiple variables that influence the intended

usage will be considered in more detail by support of the second research question. The third and last research question focused on the connection between end-user trust in AAL technology and intended usage of AAL. An extended version of the TAM by Ghazizadeh, Peng, Lee and Boyle (2012) revealed a significant connection between trust and intention to use in a questionnaire survey regarding an on-board monitoring system for commercial drivers. Another study by Jung and Loria (2010) in the context of e-health services discovered that trust in the service provider can also be important for the usage of such a technology. To examine this connection within the scope of AAL, the last research question is formulated:

3) *What is the impact of trust in AAL on the intended usage of an AAL system?*

The factors that influence trust in AAL and the intended usage are investigated by qualitative as well as quantitative research. Due to the extent and relevance of the second and third research questions for the results of the present thesis, answers for both questions can be found in the research *article 2* (see Steinke et al. 2014), *article 3* (see Steinke et al. 2014) and *article 4* (see Steinke et al., 2014). In the following section, the overall research structure of this thesis, as well as the methodology of the four research articles, is described.

4. METHODOLOGY

The methodology section begins with a graphical presentation of the research approach used within this thesis. For a more precise delimitation of the four research articles (beginning with *article 1;* Steinke et al., 2012a), an overview about the research phases, the previously-defined research questions, as well as the summary of the research methods and objectives, these details can be found in Figure 3. Furthermore, explanations about the sampling, experimental design, and procedure of the studies and their correlations among each other are presented in detail in this section.

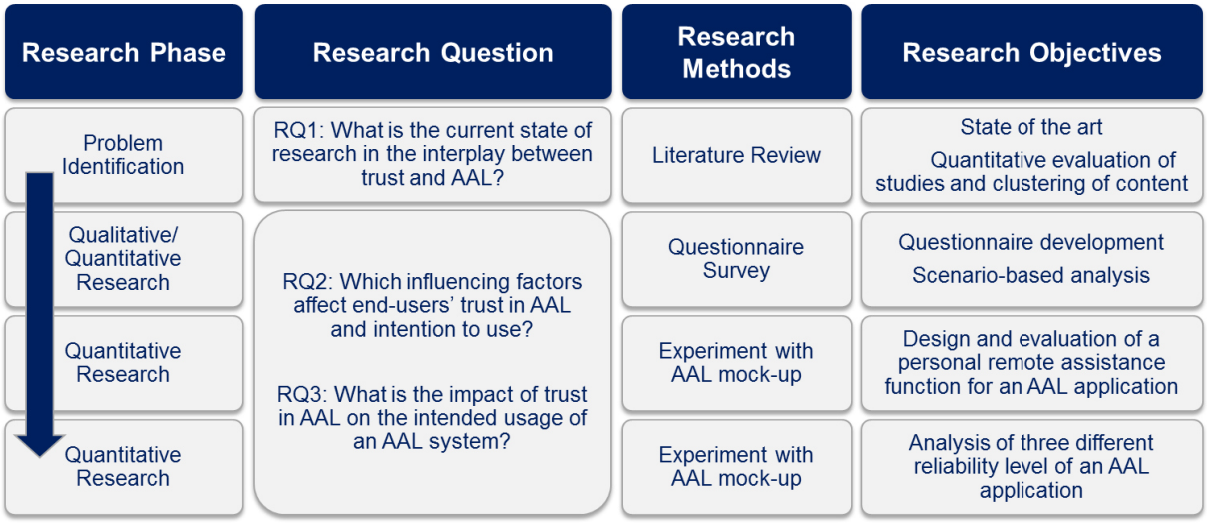


Figure 3. Summary of the research structure

To establish an overview of the state of the art regarding the literature of trust in automation, healthcare technology and AAL, a literature review was performed that spanned research published through January 2011 (see *article 1*; Steinke et al., 2012a). This research method was used to ascertain answers to the first research question. 150 computerized searches were conducted using three online bibliographic databases to identify the relevant studies. For a pre-selection process, an initial topic-related analysis of title and abstract was performed. Due to the large number of search results, this procedure was useful to reduce the number of full text articles, which were examined using five inclusion criteria. Finally, 92 articles were analyzed in detail. As position in the research landscape within the cluster 'Healthcare and assistance systems,' AAL was not even mentioned explicitly in any of the studies that addressed the issue of trust. Based on the influencing factors and variables that were

integrated into the qualitative as well as quantitative studies in this cluster, the questionnaire for the further thesis was developed.

This questionnaire forms the key element of this thesis and was especially oriented toward the understanding of the elderly target group (see *article 2*; Steinke et al., 2014). Several variables from the TAM (Davis, 1989) serve as the foundation of the questionnaire. These variables included perceived ease of use, perceived usefulness, and intention to use, as well as the variable of trust in AAL, which is based on adapted questions by Jian, Bisanz and Drury (2000) in the context of trust in automation. Moreover, the final questionnaire includes the following items: expected reliability, interest in technology, information procurement and perceived health status. Demographic data and personal information (e.g. living condition) are collected as well. During the development of the questionnaire, it was deemed necessary to keep this questionnaire as minimal as possible, wherefore the original scales were partly reduced and adapted for this topic and target group. Due to the fact that the chosen target group in *article 2* (Steinke et al., 2014) included one subgroup in which people with need for assistance in daily life (care level 1; Bundesministerium für Gesundheit, 2013) were surveyed, this action was closely connected with the success of the study. A response rate of 53% overall, and 49% in the subgroup with participants with care level 1, can be viewed positively.

To support the questionnaire study, a scenario-based design (Caroll, 2000) was used. Two scenarios in a home environment were used for an explanation of the AAL technology and as a basis for evaluation. Based on the requirement analysis by Steinke, Fritsch, Brem and Simonsen (2012b), in which the elderly preferred sensors in the home surroundings over sensors on the body or on clothing, all scenarios used fixed sensors in the home environment. The first scenario described an emergency situation in which a person fell in his home environment and was not able to stand up alone. The installed AAL solution automatically triggered an emergency call, by which an emergency physician was notified. In the second scenario, a person forgot to turn of the stove when leaving home and the AAL technology gives a reminder that no critical situation may arise during the absence. The complete scenario descriptions can be found in *article 2* (Steinke et al., 2014). Finally, 292 fully completed questionnaires by participants from the age of 50 to 93 years (mean age = 74.38; SD = 10.01) have been received.

The developed questionnaire was also used in a slightly adapted version for the following two experiments. Starting with the basics of both experiments, a tablet computer was used. All experimental tasks are embedded in situations that may emerge in a home environment. The participants are required to operate the device by finger pressure on a touch screen surface. The mock-ups that were designed for the experiments derived from the module "Meine Wohnung" (my home) from the holistic AAL prototype (Fraunhofer ISST, 2013), which was part of the research project SMILEY. Both experiments were conducted with an intervention group and a control group. For the intervention group, the minimum age in each experiment was 60 years. The control groups were composed of students. Figure 4 gives an overview of the four studies considered within the present thesis.

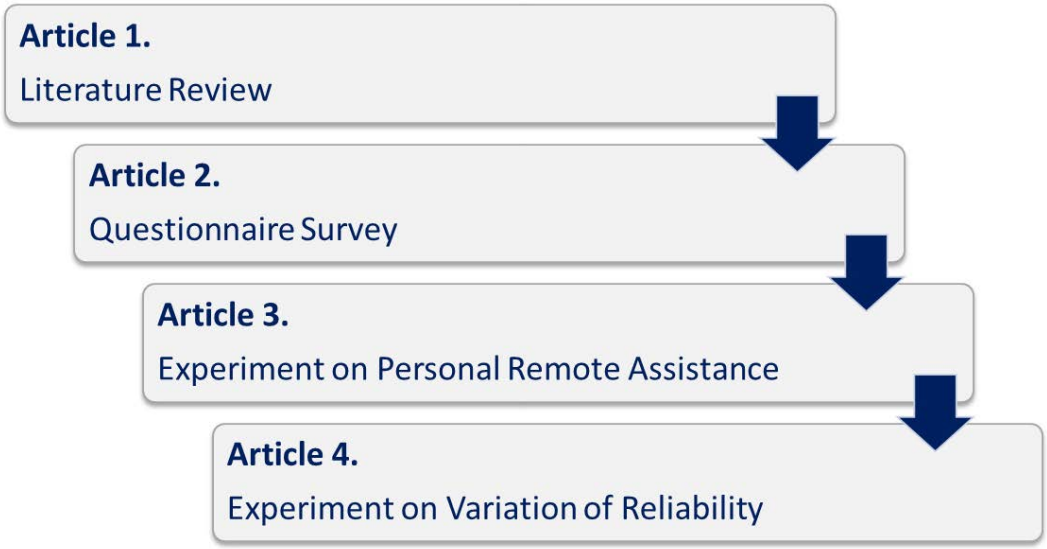


Figure 4. Visualization of the article structure of this thesis

The first experiment (see *article 3*; Steinke et al., 2014) used three different scenarios, each of which had to be completed by each of the participants. Since it was not possible to cover an emergency situation like a downfall in an AAL scenario realistically, the three scenarios that were utilized were selected for the local conditions of an experimental study. The experimental design of the first scenario focused on a "stove scenario," which derived from *article 2* (Steinke et al., 2014). In this scenario, the participant has to use the mock-up to check whether the stove is turned off correctly. If not, the participant's task is to turn off the stove via remote touch operation. Additionally, two scenarios with tasks for controlling the status of lights and windows were chosen as AAL functions that are intended to protect the house against burglary. In the scenario "light," the task was to switch on the lights and

therefore to simulate that the house is inhabited. In the "window scenario," the participants were tasked with controlling the window in the bedroom. The participant was asked to close this window in case that it is still open. The participants were given ten minutes time to solve each of the tasks.

The added value of this experiment was created by two different support functions for solving the tasks within the scenarios. Thus, the experimental design was differentiated in support of the older participants when using AAL by

a) personal remote assistance (PRA) and

b) embedded technical assistance (ETA).

In the PRA condition, which was provided for the older participants only, the simulated service provider was able to communicate via AAL application surface by video telephony with the participant. Moreover, the service provider was able to click actively on the desired icons via remote control in case that communication via video telephony was insufficient for solving the task by the participant. PRA occurred, on the one hand, as push support automatically after five minutes or, on the other hand, as pull support by telling the keyword "help" at any time, even if the five minutes had not elapsed. In both cases, the simulated service provider appears in the upper right corner of the display and the participant can decide which type of support seems to be helpful (a screenshot of the design can be found in *article 3*; Steinke et al. 2014). In the side room, the second investigator simulated the service provider by using a laptop computer and a head set for communicating via video telephony. The second support function was called embedded technical assistance (ETA). Contrary to the PRA condition, participants in the ETA condition received support via technical push function. After 30 seconds without correct click by the participant, the technical support function highlighted the button that had to be tapped next. No personal assistance was available in this experimental design, and the technical support could not be accelerated by saying the word "help." In general, 53 participants successfully completed the experiment. The 32 elderly subjects (mean age = 69.84; SD = 6.31; range = 60-84 years) were randomly divided into the two conditions, PRA (n = 15) and ETA (n = 17), to prevent the occurrence of any systematic differences before the experiment began. As mentioned previously, the 21 students from the control group (mean age = 24.71; SD = 2.10; range = 22-29 years) were only examined with technical support.

The second experiment focused on the importance of reliability in AAL (see *article 4*; Steinke et al., 2014). The above-described mock-up was adapted so that each participant had to solve 30 tasks in seven different rooms within a virtual apartment. Analogous to the first experiment, participants were asked to control the status of the stove, lights and windows. Additionally, reducing the temperature of the heating or switching on the alarm device are further tasks that were required to be solved. The complete task list can be found in *article 4* (Steinke et al., 2014). The value of this second experiment can be seen in the three different reliability conditions (80%, 90% or 100%), which were modeled in the mock-up. To gain knowledge about the different expectations regarding reliability in AAL in contrast to other daily life technologies (e.g. dishwasher or personal computer), an online questionnaire with 206 participants (mean age = 38.0; SD = 17.0; range = 14 to 88 years) was conducted beforehand (Steinke et al., 2013). The three AAL scenarios in this online questionnaire were comparable to those used in *article 3* (Steinke et al., 2014). The overall expectation for the AAL scenarios with nearly 95% expected reliability led to the gradation into the three reliability conditions.

Within the experiment, all participants were required to perform the tasks in an equal predetermined sequence, and each participant completed only one out of the three reliability conditions. 60 participants, 30 older in the intervention (mean age = 70.80; SD= 7.18; range= 61 to 85 years), as well as 30 younger in the control group (mean age= 24.33; SD= 2.41; range= 20 to 29 years) were randomly distributed to three experimental conditions each. In contrast to the experimental condition with 100% actual reliability, in the other conditions with 90% and 80% reliability, three or six error messages, respectively, pop up in the series of 30 tasks. The mock-up was developed to the effect that only correct error messages occurred. The error message stated that the operation could not be performed successfully. After the appearance of an error message, the participant was able to perform the single task a second time. At the second attempt, no further error message by the automation occurred in the case that the task was solved correctly. The time to complete the 30 tasks was not limited, in contrast to the previous experiment.

Additionally, participants were given the opportunity to check whether their actions were selected correctly in both experiments. A “checking operation” was integrated into the mock-up to voluntarily monitor the state of the performance. To prevent the participants from using this function every time, whether the participant had doubts regarding the correct

functionality, or only queried this function for curiosity reasons, mathematical tasks were implemented as artificial barriers to increase the costs of such queries (Ho et al. 2005). The four arithmetical tasks including basic calculating methods with response options from one to nine; these tasks functioned like a transaction authentication number (TAN) for online banking. The camera view (e.g. from the stove that had been successfully shut off) was only displayed when all four mathematical tasks were solved correctly (screenshots can be found in *article 4*; Steinke et al., 2014). Otherwise, participants were given no additional visual confirmation that the task was solved successfully. The virtual camera view, moreover, should hide the fact that the application itself was not performing any task in reality, since the prototype was not far enough advanced to execute such actions.

In addition to the former mentioned variables from the questionnaire study (see *article 2*; Steinke et al., 2014), some further variables are examined during the two experiments. The differentiation between the two types of assistance and the percentage of solved tasks was analyzed in the first experiment, as well as the three reliability conditions and the variable of general trust in the second experiment. During the experiments, perceived reliability was measured since participants had evaluated their experiences with AAL reliability in contrast to the variable expected reliability in the questionnaire study. The term “perceived reliability” is used in the following description, for the purpose of achieving a consistent use of the variables ”expected reliability” and “perceived reliability.” Additionally, participants’ performance was measured by the number of clicks and investment of time as well as by the amount of checking operations in both experiments. Finally, the differentiation between older intervention and younger control groups can be evaluated. For these analyses, the data were investigated on the basis of descriptive statistics, correlations, and analyses of variances and regressions. All statistical analyses were conducted by using SPSS version 17 and following.

In the next section, the results of the four research articles are presented along with the previously-defined research questions.

5. RESULTS

This results section is structured with regard to the research questions presented in this thesis. The results from the literature review provide answers to the first question, whereas the results from the other three studies supply information about the second and third research question (visualization can be found in Figure 3 in Methodology). As mentioned above, the findings within the present thesis should not be interpreted as complete and final answers to the questions posed, since research on trust in AAL is still at an early stage.

1) *What is the current state of research in the interplay between trust and Ambient Assisted Living (AAL)?*

The research of the scientific landscape at the beginning of this work led to the conclusion that the interplay between trust and AAL is worthy to be explored. As seen in the background section, the demographic development in Germany emphasizes the needs of a growing elderly population. The lack of professional caregivers and the decrease of family care (Geiger, 2009) furthermore represent an opportunity for AAL technology to support the aging society in a home environment. Also, in residential home care units, information and communication technology (ICT) can support interconnectedness and social stimulation (Chaumon, Michel, Tarpin Bernard and Croisile, 2014). Usage of AAL could extend and promote impaired peoples' personal independence in the event that the technology is market-ready. The combination of different components into a holistic AAL solution is a challenge for industry and research (European Ambient Assisted Living Innovation Alliance, 2010). Since 2005, studies on trust and healthcare or assistance systems have increased (see *article 1*; Steinke et al. 2012a). Contrary to trust research in other automation systems, this research field is still at an early stage.

In contrast to studies in other fields of automation, in which the elderly are only sporadically involved (e.g. in: McCloskey, 2006; Roberts, Ghazizadeh, and Lee, 2012; Sanchez, Rogers, Fisk, and Rovira, 2014), in studies regarding trust in medical or assistance technology, this target group is more represented (Chen and Chan, 2014; Harrefors, Axelsson and Sävenstedt, 2010; Ho et al., 2005). Before starting research activities on trust in AAL in 2010 by the author, no published studies on this topic had existed (see *article 1*; Steinke et al., 2012a). In 2013, Heydenbluth picked up the theme and examined the connection of trust in AAL systems

(Heydenbluth, 2013). To contextualize our terminology, it should be mentioned that the term "AAL" is mainly used in the European Union and not in the worldwide scientific community, in which, for example, the term "home automation" is used more frequently. Moreover, studies regarding the acceptance of (tele-)medical technology are existent (Wilkowska, Gaul and Ziefle 2010; Ziefle, Himmel and Wilkowska, 2011; Ziefle, Klack, Wilkowska and Holzinger, 2013). In terms of the demographic shift, it could be helpful to investigate this topic in more detail and to discuss it more emphatically in economics and politics.

Article	Participants	Age (Mean ± SD; Range)	Variables	Major Findings
Literature Review	-	-	-	• No research articles regarding trust in AAL existent • 18 articles considering trust in healthcare and assistance systems since 2002 • Only limited quantitative results
Question-naire Survey	N = 292 Split of 140 persons with care level 1 and 152 without any care level	Total sample = 74.4±10.0; 50-93 Care level 1 = 78.2±9.5; 51-93 Without care level = 70.9±9.1; 50-90	Age; Care Level Status (CL); Expected Reliability (ER); Gender; Housing Situation (HS); Information Procurement (IP); Intention to Use (IU); Interest in Technology (IT); Perceived Ease of Use (PEOU); Perceived Health Status (PHS); Perceived Usefulness (PU); Trust in AAL (T_{AAL})	• IU is positively influenced by T_{AAL} • T_{AAL} is positively influenced by ER; PEOU and PU • IU is positively influenced by IP; IT and PHS • People with need for care (care level 1) showed lower T_{AAL} and IU values than people without need for care
Experiment on Personal Remote Assistance	N = 53 N_{old} = 32 N_{young} = 21	Senior sample = 69.84±6.31; 60-84 Junior sample = 24.71±2.10; 22-29	**Questionnare Data:** Age; Gender; IU; T_{AAL}; PEOU; Perceived Reliability (PR); PU; **Experimental Data:** Investment of Time; Number of Checking Operations; Number of Clicks; Task Processing; Type of Assistance	• No significance between type of assistance and T_{AAL} as well as IU • Personal remote assistance leads to higher number of solved tasks and higher PEOU • T_{AAL} is positively influenced by PEOU and PR • IU is positively influenced by PU • No sign. correlation between IU and T_{AAL}
Experiment on Variation of Reliability	N = 60 N_{old} = 30 N_{young} = 30	Senior sample = 70.80±7.18; 61-85 Junior sample = 24.33±2.41; 20-29	**Questionnare Data:** Age; Gender; General Trust in Technology; IU; T_{AAL}; PEOU; PR; PU **Experimental Data:** Investment of Time; Number of Checking Operations; Number of Clicks; Reliability Level	• Reliability Level had no significant influence on T_{AAL} and IU • PR had a significant positiv influence on T_{AAL} and IU • T_{AAL} is positively influenced by PEOU • IU is positively influenced by PU and T_{AAL}

Figure 5. Summary of major findings, variables and sample details about the research articles

Figure 5 gives an overview of the samples, analyzed variables, and the major findings from the four research articles that build the basis of the present thesis. This summary should be used as entry point for a holistic combination of identic results and differences by aim of the second and third research questions.

2) Which influencing factors affect end-users' trust in AAL and intention to use?

Beginning with the second research question, the results of the questionnaire survey and of the two experiments are presented. Since the questionnaire from *article 2* (Steinke et al., 2014) was also used in slightly adapted form in both experiments, the findings can be compared alongside each other. In general, it can be said that the studies revealed some continually occurring as well as changing results between the studies. Firstly, stable results that can be seen across all studies (see *article 2* (Steinke et al., 2014), *article 3* (Steinke et al., 2014) and *article 4* (Steinke et al., 2014) are the connections between the variables of perceived ease of use as well as perceived reliability and end-users' trust in AAL. Trust in AAL was positively influenced by these two variables.

Regarding the variable of perceived ease of use, participants who perceived the mock-ups as more understandable and easy to operate or the assistance function as easy to use have shown a positive connection to trust in AAL. This result is comparable to findings in other areas such as electronic commerce (e-commerce) (Gefen, Karahanna and Straub, 2003) or electronic customer relationship management (eCRM), in which online trust was influenced by perceived ease of use (Hwang, 2009). According to both types of assistance, which are examined in *article 3* (Steinke et al. 2014), PRA influenced the elderly subject base's perceived ease of use positively. In this experiment, PRA can be seen as a satisfaction driver, which acts as a motivator (Herzberg, Mausner and Snyderman, 1959) for the end-user since it was not expected for an AAL application. Moreover, PRA leads to higher number of solved tasks in general and can be illustrated by the fact that approximately 53% of the participants with this assistance type have solved all three tasks of the experiment correctly, whereas only 12% of participants with ETA achieved this level of success. Regarding perceived ease of use, support by a human operator via video telephony appears to be more comfortable than technical assistance without a personal component. Despite this fact, the data revealed that the type of assistance had no direct significant correlation with T_{AAL} or intention to use.

Perceived reliability is the second variable that constantly influenced trust in AAL across all studies. The participants' expectations about the functionality of AAL technology in the two described scenarios ("fall" and "stove") in the questionnaire study as well as the perception of the functionality in both experiments had a positive correlation to trust in AAL by the participants.

Moreover, the results from *article 4* (Steinke et al., 2014) exhibit that a distinction exists between older persons' perceived reliability of AAL technology and its actual reliability. The actual reliability of AAL was manipulated and divided into three levels. The results revealed that the manipulation was not perceived equally and was thus interpreted in different ways by the participants. These results can be supported by Dzindolet and colleagues (2002), who determined that participants assessed the reliability of a combat identification system inaccurately in cases when they did not completely understand how the automation worked and why errors of the automated aid occurred. Perceived reliability of the AAL application was positively linked with trust in AAL, despite the fact that these three different reliability levels were presented. There was a tendency in the results showing that actual reliability of the AAL application could have an influence on trust, but in reality there was no evidence for a significant correlation. The values for perceived reliability, trust in AAL, and intention to use do not differ significantly between the 80%, 90% and 100% reliability conditions.

In addition to the stable positive connection of perceived reliability and perceived ease of use on trust in AAL, the factor of perceived usefulness has a positive influence across all studies. In contrast to both of the influencing factors described before, the influence of perceived usefulness was ambiguous since there was a significant positive influence on T_{AAL} in the questionnaire survey but no further evidence for this linkage with trust in the following two experiments. Within the experiment incorporating both additional assistance types for AAL, the connection between trust in AAL and perceived usefulness was disproved and instead of this, a significant influence on intention to use was revealed (see *article 3*; Steinke et al., 2014). The following experiment supported this statement and revealed a positive influence of perceived usefulness on intention to use, mediated by perceived reliability. Support of the connection between perceived usefulness of an AAL system as a positive factor for the (intended) usage by the end-user can be found in various other research areas. Perceived usefulness was the determinant for usage of e-commerce (Pavlou, 2001), or behavioral intention to use distraction mitigation systems (Roberts, Ghazizadeh and Lee, 2012). As a further example, Horst, Kuttschreuter and Gutteling (2007) discovered that the intention to use electronic-government (e-government) services was determined by perceived usefulness.

With respect to further results from the studies, the variables of information procurement and interest in technology show positive influence on older persons' intention to use AAL. The

additional information gained by information procurement offers a better understanding and knowledge about a new technology. Older persons who consult their relatives or friends before purchasing a new product have shown significantly higher intention to use values. The results from the questionnaire study also revealed that people who are more interested in new electronic devices have higher intention to use AAL. The differentiation between participants with need for care (care level 1) and without care level have proven to be interesting findings for developers of AAL and for marketing strategists. The results demonstrated that people with care level 1 who require support in various activities of daily life had lower values of trust in AAL and intention to use AAL than people without health restrictions. Since this finding, as well as the connection between trust and chronological age, was only significant in this study, this topic will be picked up in the discussion section (for details see *article 2*; Steinke et al. 2014). Regarding the third research question:

3) *What is the impact of trust in AAL on the intended usage of an AAL system?*

There is a variety of results that should be mentioned and discussed in detail. The impact of end-users' trust in AAL on intention to use was not stable across the three studies. The results from the questionnaire survey revealed a significant connection between both of these variables. In *article 2* (Steinke et al., 2014), trust in AAL had the largest impact on intention to use in comparison to all other variables. Based on the previously described variables of perceived usefulness, perceived reliability, and perceived ease of use, all of which had a positive influence on trust, the intended usage was also significant positively influenced by trust in AAL. Moreover, the results from *article 4* (Steinke et al., 2014) supported this connection and also found a positive influence of trust in AAL on intention to use. Contrarily, these findings were not supported by *article 3* (Steinke et al., 2014), in which intention to use was only positively influenced by perceived usefulness and not by trust in AAL. In the following section, possible reasons for these varying results and further topics will be discussed in more detail.

6. DISCUSSION

In the following section, an overall discussion about the results of this thesis is presented. As seen previously, some results are stable among the four research articles, whereas other findings differed depending on the research design. First of all, the different results in terms of the connection between trust in AAL and intention to use needs to be discussed. As seen in the Results section, two out of three studies confirmed the statement that intention to use is positively influenced by trust in AAL. *Article 2* (Steinke et al., 2014) shows a strong significant positive connection. The target group in this study includes people with and without care level 1, which had a higher mean age and more physical handicaps. Contrary to both of the subsequent experiments, the scenario "fall," as a highly critical scenario, was only investigated in the questionnaire survey. Moreover, the sample size (with 292 participants over 50 years) was nearly ten times as large as the senior samples in both experiments. Studies from various research fields such as e-commerce (Awad and Ragowsky, 2008; Gefen et al., 2003), e-government service (Carter and Bélanger, 2005; Warkentin, Gefen, Pavlou, and Rose, 2002) or driving assistance via on-board monitoring system (Ghazizadeh et al., 2012) support the positive connection between trust and intention to use.

Compared with driving assistance automation, in which the driver can manually intervene while driving, the degree of automation in AAL is higher. In AAL technology, the end-user has no possibility to act manually in case of an emergency, and no human supervision in the home environment is available. In other domains, the human can often correct errors of the technology on their own, if they are paying attention or have the necessary skills. In AAL, the emergency cascade is initiated solely by technology, and end-users are required to trust the automated system. Also, the service provider can only rely on the technical alert. By usage of the fall sensors, the end-user has to trust permanently in the monitoring by technology. Regarding most of the scenarios in the experiments, a healthy end-user could, for example, close the window or turn off the light manually in case that he is on-site. But in case of need, for which AAL technology is designed, the impaired person has to rely on the functionality of AAL. The positive correlation between trust in AAL and intention to use can also be supported by the results from the experiment in *article 4* (Steinke et al., 2014) with 30 participants over the age of 60 years. After considering the studies from other areas, the results from the two studies (see *article 2* and *article 4*), and the other mentioned facts, the

statement is arguable that trust in AAL seems to have a positive effect on the intended usage of AAL. The results from *article 3* (Steinke et al., 2014), in which no significant correlation between both variables existed, could be attributed to the small number of participants (n=21) in the senior sample.

Next, the clear results regarding trust in AAL that are revealed within the present thesis should be discussed. The influence of perceived ease of use and perceived reliability on trust in AAL were consistent across all studies. Perceived ease of use is the degree to which a person considers that a technology can be used without effort (Davis, 1989); this metric showed a consistent positive connection with trust in AAL in the described AAL scenarios. Older end-users who often have little or no experience with a smartphone or tablet computer see the variable of ease of use as a basis for building trust in AAL. The mock-ups on the tablet computer used in the experiments seemed to have conveyed the feeling that they are easy to operate. Furthermore, not only the application but also the AAL technology as a whole could have been decisive for the positive evaluation, since this distinction is often not clear for the end-user. This evaluation of simple operability was intensified by support via PRA. Personal remote support by a simulated service provider was preferred by the participants in contrast to solely embedded technical assistance (see *article 2*; Steinke et al. 2014). This finding indicated that integrated personal assistance on request could be an important factor for increasing not only the ease of use of AAL, but also trust and intention to use in subsequent steps. PRA can be seen as a satisfaction driver (Herzberg et al., 1959; Kano, Seraku, Takahashi and Tsuji, 1984) that supports the end-user in solving the tasks via video telephony. A service provider that offered service 24 hours per day, 7 days a week, could assist end-users with daily routines, such as the replacement of batteries in their AAL sensors. On the other hand, in emergency situations a personal contact via voice or video telephony could be used as an initial aid as well as also to calm down the person until personal help arrived on-site. This connection of perceived ease of use and trust in AAL corresponds with previous studies from other research areas in which trust in automation can be seen as affected by perceived ease of use (e.g. Gefen et al., 2003; Hwang, 2009; Lee and See, 2004). Additionally, a clear structured interface with legible characters, an understandable manual, or a personal briefing before using AAL technology for the first time could lead to higher ease of use by the end-user.

The variable of perceived reliability could be identified as a further influencing factor that was consistently positively correlated with trust in AAL. This result was accompanied by previous studies in which trust in automation was affected by perceived reliability (e.g. Keller and Rice, 2010; Madhavan, Wiegmann and Lacson, 2006). The idea of AAL - supporting (impaired) persons for living a healthy and safe life in the home environment - includes the fact that the used technology had to assist the end-user perfectly at all times. As seen in Steinke et al. (2013), the participants' expectation for reliability in AAL solutions was the highest, with about 95% expected reliability for AAL compared with other daily life technologies. Despite that fact, the results of the present thesis revealed that the manipulation of actual reliability in the AAL mock-up had no significant impact on trust in AAL. This indicates that, independent from the reliability condition (80%, 90% or 100% reliability), no significant differences related to trust, intention to use, or perceived reliability were revealed.

These findings regarding trust are supported by Bagheri and Jamieson (2004) whose work revealed that trust ratings in the case of an air traffic control system did not significantly differ between various reliability conditions. In contrast, Bailey and Scerbo (2007) determined that operator trust in the context of aviation automation tasks increased as a function of increasing reliability of the system. Further studies (Rice, 2009; Rovira, McGarry, and Parasuraman, 2007; Spain and Bliss, 2008) support this positive correlation between trust and actual reliability. Different explanations for the missing significance between trust and the various reliability levels can be found. The error message seemed to have a strong impact on the perception of the participants (see *article 4*; Steinke et al., 2014). The correct error messages used in the experiment could give the appearance of a reliable AAL application, although obviously errors existed. Older people seem also to trust an AAL technology having only 80% reliability. This perception of the end-user could also result in overreliance (Dzindolet, Pierce, Beck, Dawe and Anderson, 2001; Lees and Lee, 2007; Sheridan and Parasuraman, 2005) or blind faith (Wälivaara, Andersson, and Axelsson, 2009) in AAL. From a practical viewpoint, developers should be aware that, for example, in case of changing the batteries in the installed sensors at home, very clear information and instructions for the end-users are needed to keep the equipment operational.

Regarding the intended usage of an AAL solution, both experimental studies support that perceived usefulness influenced this variable positively (see *article 3* (Steinke et al., 2014) and *article 4* (Steinke et al., 2014). As can be seen, for example in Pohlmeyer (2011),

perceived usefulness of a computer was the principal reason for older people to use this system. Moreover, the adoption of interactive technologies by older as well as younger people was influenced by perceived usefulness. Further studies in research areas of automation (Roberts et al., 2012), e-commerce (Pavlou, 2001), e-government (Horst et al., 2007), and mobile banking (Luarn and Lin, 2005) support this correlation. Wilkowska and colleagues (2010) revealed that in the context of medical devices for male users, perceived usefulness was the only variable that influenced their intention to use. In the context of AAL, end-users could appreciate perceived usefulness as one main factor for using this technology. While older people perceived the possibility to prolong their personal independence in their familiar surroundings by usage of technological support, the younger control groups had an expectation that AAL could be used to augment their comfort in order to achieve a higher quality of living. Thus, it can be seen that perceived usefulness depends essentially on personal factors.

Summarizing the main reasons for the intention to use AAL, it can be stated that the existence of trust in an AAL product as well as high values of perceived usefulness will not automatically lead to an actual usage or purchase of AAL by the end-user. The simultaneous presence of both factors seem necessary for the intention to use AAL. In case no usefulness is perceived by the end-user, trust will not compensate this lack, and a purchase decision will likely not be made. Otherwise, the presented results give reason to assume that trust in AAL is relevant in the case that perceived usefulness is existent. Therefore, the combination of both influencing factors, perceived usefulness and trust in AAL, seems to be relevant for the intention to use. Trust in AAL is moreover influenced by the variables of perceived ease of use and perceived reliability. As seen above, both of these factors show consistent correlations across all research studies of this thesis. Based on the definition of trust in AAL from *article 1* (see Steinke et al., 2012a), the new findings lead to a more refined definition:

End-user trust in AAL is influenced by perceived ease of use and perceived reliability, and could lead, in combination with the existence of perceived usefulness, to the intention to use AAL.

Returning to the starting point, the demographic shift in Germany, the results of this thesis could be considered with particular attention by developers of AAL and the industry in general. Due to the increasing technology use in all parts of society, older people are

increasingly getting in touch with technological devices such as tablet computers and smart phones. Due to the predicted lower capacity of nursing care in the upcoming decades, further effort is required to attract people to use AAL who actually need support in their living environment. In a further step, the different findings between participants with need for care (care level 1) and without care level in *article 2* (see Steinke et al., 2014) should be considered in more detail. The results demonstrated that people with care level 1 who require support in various activities of daily life had lower values of trust in AAL, as well as lower intention to use AAL than people without health restrictions. The analysis revealed that chronological age was associated with care level 1 and also with perceived health status. This means that the younger older in this study and people with better perceived health status have higher trust in AAL technology. Also, for intention to use, a positive connection with perceived health status was identified. People with better perceived health status had a higher willingness to use AAL technology. The results could be interpreted in the way that there may be fear of individuals with care level 1 who already receive support at home due to this innovative technology. Some participants could see AAL as a threat that could be used as a substitution for personal assistance in the home environment through a caregiver. This significant connection between chronological age and trust in AAL was only found in this study. This discrepancy could be explained by the larger sample size or due to the fact that it was only in this study that people with existent impairments were surveyed. From a marketing perspective, people with health restrictions as a target group for which the functionality and services of AAL are developed primarily, need to be informed and sensitized in a different way than people without these restrictions. The message should be that AAL is not developed to remove personal care from people who are in need, but to support these people in their daily lives by supplying additional technology.

As a further socio-demographic variable, the role of gender in AAL should be discussed briefly. In contrast to Steinke et al. (2012b), in which male participants showed higher trust values in AAL sensors, the research articles in the present thesis revealed no significant differences. The studies of Wilkowska and colleagues (2010) and Ziefle and Schaar (2011), in which smart textiles and invasive technical stents were investigated, revealed significant results of gender differences with respect to the acceptance of (invasive) medical technology. Moreover, for example in studies in the context of e-commerce (Awad and Ragowsky, 2008), the role of gender influenced the effect of trust on intention to use. Since women have a

higher life expectancy that men and thus live more often alone in their home environment in old age (Statistisches Bundesamt, 2012b), this target group should be sensitized to AAL usage via special marketing or information campaigns.

Additional to these results, three further important facts that will be decisive for the development of AAL in the upcoming years should be mentioned briefly. Firstly, the topic of data security and data privacy needs to considered. The interviews during the requirement analysis at the beginning of the research project SMILEY in 2011 did not reveal a high sensitivity of older persons to data security issues (Fraunhofer ISST, 2013). In the meanwhile, this topic is present in the media nearly on a daily basis. Data privacy protection and data security standards could be important for the credibility and success of AAL technology. Wilkowska and Ziefle (2012) reported that security as well as privacy aspects are important for the adaption of medical assistive technology. In particular, women and people with better health status insist on high security standards. Another study in this context revealed that the lowest priority of privacy was reported by the oldest (range 61 to 80 years) and youngest (range 20 to 30 years) participants (Wilkowska and Ziefle, 2012). Since the collection and processing of personal data is necessary in the context of AAL, providers should actively address this topic. Pavlou (2001) reported that privacy and security perceptions influenced trust in the area of e-commerce as well.

The second topic can be seen in the regulatory requirements in the context of AAL and telemedicine. In Germany, in contrast to other European countries such as Portugal (Costa, Andrade, Novais and Simoes, 2012), high legal and regulatory compliances are existent and tracked by the German Medical Products Law (Medizinproduktegesetz). On the one hand, these strict regulations try to protect the end-user against damages that occur by unfinished products or data theft/loss. On the other hand, the German regulations restrict the economic freedom of organizations and are a main reason why it is so difficult to launch marketable AAL products in Germany (Fraunhofer, 2013). Additionally to regulations by the national data protection law, it is also difficult for organizations to give a service level agreement that the technology will work perfectly without fail. Due to the importance for end-user health, a guarantee for the reliable functionality of AAL technology in cases of emergency would be desirable, but cannot be guaranteed. For example, in rural areas it currently appears difficult to provide comprehensive support.

The third topic that needs to be addressed for raising awareness and generating market penetration for AAL, is the insufficient business and price models in this market. Due to the various functionalities and services that can be offered by AAL technology, a broad target group and large market potential exist. These possibilities are exhausted so far only to a small extent, since business models and business systems are not sufficiently developed (Gersch and Liesenfeld, 2012). The design of cost-effective technical support as a medium-term goal could promote the purchase and use of AAL. For example, in case of false alarms by technical or human fault, which cause an unnecessary visit of an emergency doctor, high costs may occur. Moreover, a marketing strategy, starter packages, or discount campaigns could be used as incentives for adopting the comfort functions of AAL solutions and enable companies to achieve the critical mass of users necessary for financial feasibility faster as well as to facilitate the entry for the use of other (more critical) AAL functions.

7. CONCLUSION

It would be presumptuous to say that the present thesis has covered the complete picture of trust research in AAL. By means of the conducted literature review, the questionnaire survey, as well as both experiments, the following findings can be derived. Trust in AAL as well as perceived usefulness positively influences the intention to use AAL technology. The existence of both of these factors in combination seem to be the basis for intention to use by the end-user. Moreover, the crucial factors that are identified for trust in AAL are perceived ease of use and perceived reliability. Perceived ease of use of the interface can be seen as positive influencing factor for trust in AAL and is consistent with the results from previous studies in other areas of human-machine interaction (e.g. Lee and See, 2004; Montague et al., 2010). Moreover, the correlation between trust and perceived reliability was stable across all research articles. These factors in combination should build the fundament for design and service requirements for AAL solutions. The influence of actual reliability on trust, which was measured by the manipulation of reliability in *article 4* (Steinke et al., 2014), cannot be clearly proven in the context of AAL. A tendency of overreliance (Parasuraman and Riley, 1997) on the presented AAL system could be seen.

The functionality of AAL is manifold and thus, the end-user should decide on a personalized bundle according to their individual needs. The scenarios analyzed in the present thesis cover a broad range of AAL, but only the questionnaire study included the scenario “fall” as one of the most serious reasons for using AAL (see *article 2*, Steinke et al., 2014). Technological support in such a situation as preventing long-term injuries, for example, by informing the emergency doctor immediately, is the added value of AAL. The results of this study revealed that people who already receive support for living in their own home environment showed lower values of trust in AAL and usage intention. The fact that this target group is more skeptical in intended usage highlights the challenge for research and industry. One possible explanation could be seen in the fact that people with need for care could regard AAL as a substitution for personal assistance in the home environment and fear the adoption of this technology. Further important factors for the success of AAL in the market will be data security and privacy protection. Moreover, it will be a challenge for organizations to develop successful and sustainable price and business models for holistic AAL systems that are also affordable for the end-user.

8. OUTLOOK

In order to confirm the obtained findings and to clarify the open topics, further research will be necessary for a more detailed assessment of trust in AAL. First of all, studies for investigating the variation of actual reliability in AAL technology should be conducted to analyze whether there is a correlation with trust. Moreover, it would be interesting to determine whether there is a threshold in declining trust due to decreasing actual reliability of the AAL system. In previous studies, reliability levels between 60% and 80% represented a threshold of performance decline (Rovira et al. 2007; Wickens and Dixon, 2005). In the context of AAL applications, experiments with reliability conditions less than 80% could bring new knowledge about the perception of reliability by the end-user. Additionally, the integration of false alarms as a further error type, as well as an increase in the number of tasks or duration of the experiment, could reveal new insights for trust in AAL. External factors, personality traits (Szalma and Taylor, 2011), or different types of trust (Hoff and Bashir, 2013) could be considered for a more detailed examination in the future.

In order to establish reliable information in a real-life environment, a longitudinal study with older people would be useful. For this purpose, AAL actuators and sensors should be integrated into the participants' homes to measure actual usage over a period of several months. During this time, modifications could be made to analyze different scenarios in a field experiment. Moreover, the importance of the added value by support of "fall monitoring" could be analyzed in detail. Older persons' learning effects, trust development over time, as well as the performance of sensors and actuators in daily use could be examined. Experiments could be also conducted in rural areas, in which older persons could have different views about AAL technology in contrast to people who are living (alone) in a larger city. Due to the multiple components of AAL, examination with other types of sensors that are positioned on the body or in clothing or camera-based systems could lead to a more holistic picture (Ziefle et al., 2011). To underline the relevance of personal (remote) assistance in AAL for older users, developers could test additional sorts of remote support such as video and voice telephony or remote support without telephony. Since human-robot systems such as ASIMO (ASIMO, 2013) gain more importance, the combination with studies regarding human-robot trust (Sanders, Oleson, Billings, Chen and Hancock, 2011; Schaefer, 2013) could be relevant to the understanding of trust in AAL technology as well.

9. REFERENCES

Ambient Assisted Living Joint Programme (2013). *Catalogue of Projects 2013.* Online. Retrieved 2013/10/28, from http://www.aal-europe.eu/wp-content/uploads/2013/09/AALCatalogue2013_Final.pdf

ASIMO (2013). *Asimo The World's Most Advanced Humanoid Robot.* Online. Retrieved 2013/05/20, from http://asimo.honda.com/inside-asimo/

Awad, N. F., & Ragowsky, A. (2008). Establishing trust in electronic commerce through online word of mouth: An examination across genders. *Journal of Management Information Systems*, *24(4),* 101-121.

Backes, G. M., & Clemens, W. (2008). *Lebensphase Alter: Eine Einführung in die sozialwissenschaftliche Alternsforschung*. Weinheim: Beltz Juventa.

Bagheri, N., & Jamieson, G. (2004). The impact of context-related reliability on automation failure detection and scanning behavior systems. In *Proceedings of the 2004 IEEE International Conference on Man and Cybernetics* (pp. 212-217), 10-13 October Toronto, Canada.

Bailey, N. R., & Scerbo, M. W. (2007). Automation-induced complacency for monitoring highly reliable systems: The role of task complexity, system experience, and operator trust. *Theoretical Issues in Ergonomics Science, 8(4),* 321-348.

Belbachir, A. N., Litzenberger, M., Schraml, S., Hofstatter, M., Bauer, D., Schon, P., Humenberger, M., Sulzbachner, C., Lunden, T., & Merne, M. (2012). CARE: A dynamic stereo vision sensor system for fall detection. *Circuits and Systems (ISCAS),* 731-734.

Bundesministerium des Innern (2011). *Demografiebericht: Bericht der Bundesregierung zur demografischen Lage und künftigen Entwicklung des Land.* Rostock: Publikationsversand der Bundesregierung.

Bundesministerium für Bildung und Forschung (2008). *AAL. Altersgerechte Assistenzsysteme für ein gesundes und unabhängiges Leben. Ambient Assisted Living*. Online. Retrieved 2013/07/27, from http://www.aal-deutschland/deutschlandl-faltblatt

Bundesministerium für Bildung und Forschung (2009). *Assistenzsysteme im Dienste des älteren Menschen: Steckbriefe für ausgewählte Projekte in der BMBF Fördermaßnahme, Altersgerechte Assistenzsysteme für ein gesundes und unabhängiges Leben – AAL.* Online. Retrieved 2012/04/14, from https://ssl.vdivde-it.de/aaljp-transnationaler-informationstag/europa/dokumente/steckbriefsammlung-aal-call1_v4.pdf

Bundesministerium für Gesundheit (2013). *Pflegebedürftigkeit*. Online. Retrieved 2012/04/14, from http://www.bmg.bund.de/pflege/pflegebeduerftigkeit/pflegebeduerftigkeit.html

Caroll, J. M. (2000). Five reasons for scenario-based design. *Interacting with Computers,13,* 43-60.

Carter, L., & Bélanger, F. (2005). The utilization of e-government services: Citizen trust, innovation and acceptance factors. *Information Systems Journal, 15*, 5-25.

Chen, K., & Chan, A. H. (2014). Gerontechnology acceptance by elderly Hong Kong Chinese: A senior technology acceptance model (STAM). *Ergonomics*, *57,* 1-18.

Chaumon, M.-E. B., Michel, C., Tarpin Bernard, F., & Croisile, B. (2014). Can ICT improve the quality of life of elderly adults living in residential home care units? From actual impacts to hidden artefacts. *Behaviour & Information Technology, 33(6),* 574-590.

Costa, A., Andrade, F., Novais, P., & Simoes, R. (2012). Privacy and data protection in elderly healthcare: Threats and legal warranties. In *Proceedings of the Sixth International Workshop on Juris-informatics* (pp. 7-20).

Davis, F. D. (1989). Perceived usefulness, perceived ease of use, and user acceptance of information technology. *MIS Quarterly, 13*, 319-340.

de Vries, P., Midden, C., & Bouwhuis, D. (2003). The effects of errors on system trust, self-confidence, and the allocation of control in route planning. *International Journal of Human-Computer Studies, 58*, 719-735.

Dixon, S. R., & Wickens, C. D. (2006). Automation reliability in unmanned aerial vehicle control: A reliance-compliance model of automation dependence in high workload. *Human Factors, 48,* 474-486.

Dzindolet, M. T., Pierce, L. G., Beck, H. P., & Dawe, L. A. (2002). The perceived utility of human and automated aids in a visual detection task. *Human Factors, 44,* 79-94.

Dzindolet, M. T., Pierce, L. G., Beck, H. P., Dawe, L. A., & Anderson, B. W. (2001). Predicting misuse and disuse of combat identification systems. *Military Psychology, 13(3)*, 147-164.

Ezer, N., Fisk, A. D., & Rogers, W. A. (2008). Age-related differences in reliance behavior attributable to costs within a human-decision aid system. *Human Factors, 50,* 853-863.

Fishbein, M., & Ajzen, I. (1975). *Belief, attitude, intention and behavior: An introduction to theory and research.* Massachusetts: Addison-Wesley.

Fraunhofer ISST (2013). *Smart and Independent Living for the Elderly – SMILEY: Projektabschlussbericht*. Online. Retrieved 2013/04/14, from http://www.isst.fraunhofer.de/content/dam/isst/de/documents/Forschungsnews/Fraunhofer-ISST_SMILEY-Schlussbericht_1.1.pdf

Gao, J., Lee, J. D., & Zhang, Y. (2006). A dynamic model of interaction between reliance on automation and cooperation in multi-operator multi-automation situations. *International Journal of Industrial Ergonomics, 36,* 511-526.

Gefen, D., Karahanna, E., Straub, D. W. (2003). Trust and TAM in online shopping: An integrated model. *MIS Quarterly, 27(1),* 51-90.

Geiger, M. (2009). *Pflege in einer alternden Gesellschaft: Projekt - Perspektiven auf den demografischen Wandel.* Saarbrücken: Institut für Sozialforschung und Sozialwissenschaft e.V.

Gersch, M., & Liesenfeld, J. (2012). *AAL- und E-Health-Geschäftsmodelle: Technologie und Dienstleistungen im demografischen Wandel und in sich verändernden Wertschöpfungsarchitekturen.* Wiesbaden: Gabler.

Ghazizadeh, M., Peng, Y., Lee, J. D., & Boyle, L. N. (2012). Augmenting the technology acceptance model with trust: Commercial drivers' attitudes towards monitoring and feedback. *Proceedings of the Human Factors and Ergonomics Society Annual Meeting, 56,* 2286-2290.

Giesecke, S., Hull, J., Schmidt, S., Strese, H., Weiß, C., & Baumgarten, D. (2005). *Ambient Assisted Living*. Country Report Germany.

Harrefors, C., Axelsson, K., & Sävenstedt, S. (2010). Using assistive technology services at differing levels of care: Healthy older couples' perceptions. *Journal of Advanced Nursing, 66(7),* 1523-1532.

Hellman, R. (2012). *Mylife -Multimedia technology to support independence for and participation by people with dementia (2011-202).* Online. Retrieved 2013/10/28, from http://www.karde.no/MYLIFE_english.html

Herzberg, F., Mausner, B., & Snyderman, B. B. (1959). *The motivation to work (2nd ed.).* New York: John Wiley.

Heydenbluth, C. (2013). *To trust or not to trust: Wann vertrauen Menschen in technologische Systeme?* Bachelor thesis, Humboldt-Universität zu Berlin, Germany.

Ho, G., Wheatley, D., & Scialfa, C. T. (2005). Age differences in trust and reliance of a medication management system. *Interacting with Computers, 17,* 690-710.

Hoff, K., & Bashir, M. (2013). A theoretical model for trust in automated systems. In *CHI'13 Extended Abstracts on Human Factors in Computing Systems* (pp. 115-120), New York, USA.

Horst, M., Kuttschreuter, M., & Gutteling, J. M. (2007). Perceived usefulness, personal experiences, risk perception and trust as determinants of adoption of e-government services in the Netherlands. *Computers in Human Behavior, 23(4),* 1838-1852.

Hu, P. J., Chau, P. Y. K., Liu Sheng, O. R., & Yan Tam, K. (1999). Examining the technology acceptance model using physician acceptance of telemedicine technology. *Journal of Management Information Systems, 16(2),* 91-112

Hwang, Y. (2009). The impact of uncertainty avoidance, social norms and innovativeness on trust and ease of use in electronic customer relationship management. *Electronic Markets, 19(2-3),* 89-98.

Jian, J.-Y., Bisanz, A. M, & Drury, C. G. (2000). Foundations for an empirically determined scale of trust in automated systems. *International Journal of Cognitive Ergonomics, 4,* 53-71.

Jung, M.-L., & Loria, K. (2010). Acceptance of swedish e-health services. *Journal of Multidisciplinary Healthcare, 3,* 55-63.

Kano, N., Seraku, N., Takahashi, F., & Tsuji, S. (1984). Attractive quality and must-be quality. *The Journal of the Japanese Society for Quality Control, 14(2),* 39-48.

Keller, A., & Rice, S. (2010). System-wide versus component-specific trust using multiple aids. *The Journal of General Psychology, 137,* 114-128.

Lee, J. D., & Moray, N. (1992). Trust, control strategies and allocation of function in human-machine systems. *Ergonomics, 35,* 1243-1270.

Lee, J. D., & Moray, N. (1994). Trust, self-confidence, and operators' adaptation to automation. *International Journal of Human-Computer Studies, 40,* 153-184.

Lee, J. D., & See, K. A., (2004). Trust in automation: Designing for appropriate reliance. *Human Factors, 46,* 50-80.

Lees, M. N., & Lee, J. D. (2007). The influence of distraction and driving context on driver response to imperfect collision warning systems. *Ergonomics, 50(8),* 1264-1286.

Lewandowsky, S., Mundy, M., & Tan, G. P. A. (2000). The dynamics of trust: Comparing humans to automation. *Journal of Experimental Psychology, 6(2),* 104-123.

Luarn, P., & Lin, H. H. (2005). Toward an understanding of the behavioral intention to use mobile banking. *Computers in Human Behavior*, *21(6),* 873-891.

Ma, Q., & Liu, L. (2004). The technology acceptance model: A meta-analysis of empirical findings. *Journal of Organizational and End User Computing, 16(1),* 59-72.

Madhavan, P., & Wiegmann, D. A. (2007). Similarities and differences between human–human and human–automation trust: An integrative review. *Theoretical Issues in Ergonomics Science, 8(4),* 277-301.

Madhavan, P., Wiegmann, D. A., & Lacson, F. C. (2006). Automation failures on tasks easily performed by operators undermine trust in automated aids. *Human Factors, 48,* 241-256.

McCloskey, D. W. (2006). The importance of ease of use, usefulness, and trust to online consumers: An examination of the technology acceptance model with older customers. *Journal of Organizational and End User Computing, 18*(3), 47-65.

McGuirl, J. M., & Sarter, N. B. (2006). Supporting trust calibration and the effective use of decision aids bypresenting dynamic system confidence information. *Human Factors, 48(4),* 656-665.

Merritt, S. M. (2011). Affective processes in human–automation interactions. Human Factors. *The Journal of the Human Factors and Ergonomics Society, 53(4),* 356-370.

Merritt, S. M., & Ilgen, D. R. (2008). Not all trust is created equal: Dispositional and history-based trust in human automation interactions. *Human Factors, 50,* 194-210.

Merritt, S. M., Heimbaugh, H., LaChapell, J., & Lee, D. (2013). I trust it, but I don't know why: Effects of implicit attitudes toward automation on trust in an automated system. *Human Factors, 55(3),* 520-534.

Montague, E. N. H., Winchester III, W. W., & Kleiner, B. M. (2010). Trust in medical technology by patients and healthcare providers in obstetric work systems. *Behaviour and Information Technology, 29,* 541-554.

Moray, N., Inagaki, T., & Itoh, M. (2000). Adaptive automation, trust, and self-confidence in fault management of time-critical tasks. *Journal of Experimental Psychology, 6,* 44-58.

Muir, B. M. (1987). Trust between humans and machines, and the design of decision aids. *International Journal of Man Machine Studies, 27,* 527-539.

Muir, B. M., & Moray, N. (1996). Trust in automation: Part II. Experimental studies of trust and human intervention in a process control simulation. *Ergonomics, 39(3),* 429-460.

National Transportation Safety Board (1997). *Grounding of the panamanian passenger ship royal majesty on rose and crown shoal near Nantucket.* Online. Retrieved 2014/04/14, from www.ntsb.gov/doclib/reports/1997/mar9701.pdf

Neyedli, H. F., Wang, L., Jamieson, G. A., & Hollands, J. G. (2010). Evaluating reliance on combat identification systems: The role of reliability feedback. In D. H. Andrews, R. P. Herz, & M. B. Wolf, (Eds.), *Human factors issues in combat identification* (pp. 249-264). Burlington: Ashgate.

Nikolaos, B. (2014). *Managing older people social relationships for better communication, activation and interaction.* Online. Retrieved 2014/04/14, from http://www.elderspaces.eu/

Parasuraman, R., & Miller, C. (2004). Trust and etiquette in high criticality automated systems. *Communications of the Association for Computing Machinery, 47,* 51-55.

Parasuraman, R., & Riley, V. (1997). Humans and automation: Use, misuse, disuse, abuse. *Human Factors, 39(2),* 230-253.

Paulus, W., Hilbert, J., & Potratz, W. (2009). ICT for housing. In N. Malanowski, & M. Cabrera, (Eds.), *Information and Communication Technologies for Active Ageing: Opportunities* and *Challenges for the European Union* (pp. 205-215). Amsterdam: IOS Press.

Pavlou, P. (2001). Integrating trust in electronic commerce with the technology acceptance model: Model development and validation. *Americas Conference on Information Systems, 159*, 816-822.

Pohlmeyer, A. E. (2011). *Identifying attribute importance in early product development: Exemplified by interactive technologies and age.* PhD thesis, Technische Universität Berlin, Germany.

Rice, S. (2009). Examining single- and multiple-process theories of trust in automation. *The Journal of General Psychology, 136(3),* 303-319.

Roberts, S. C., Ghazizadeh, M., & Lee, J. D. (2012). Warn me now or inform me later: Drivers' acceptance of real-time and post-drive distraction mitigation systems. *International Journal of Human-Computer Studies, 70(12),* 967-979.

Rotter, J. B. (1967). A new scale for the measurement of interpersonal trust. *Journal of Personality, 35,* 651-665.

Rovira, E., McGarry, K., & Parasuraman, R. (2007). Effects of imperfect automation on decision making in a simulated command and control task. *Human Factors, 49(1),* 76-87.

Sanchez, J., Rogers, W. A., Fisk, A. D., & Rovira, E. (2014). Understanding reliance on automation: Effects of error type, error distribution, age and experience. *Theoretical Issues in Ergonomics Science, 15(2),* 134-160.

Sanders, T., Oleson, K. E., Billings, D. R., Chen, J. Y., & Hancock, P. A. (2011). A model of human-robot trust. Theoretical model development. *Proceedings of the Human Factors and Ergonomics Society Annual Meeting, 55,* 1432-1436 .

Schaefer, K. E. (2013). *The perception and measurement of human-robot trust.* PhD thesis, University of Central Florida, Florida.

Sheridan, T. B., & Parasuraman, R. (2005). Human-Automation interaction. *Reviews of Human Factors and Ergonomics, 1,* 89-129.

Singh, I. L., Molloy, R., & Parasuraman, R. (1993). Automation-induced "complacency": Development of the complacency-potential rating scale. *The International Journal of Aviation Psychology, 3(2),* 111-122.

Spain, R. D., & Bliss, J. P. (2008). The effect of sonification display pulse rate and reliability on operator trust and perceived workload during a simulated patient monitoring task. *Ergonomics, 51(9),* 1320-1337.

Statistische Ämter des Bundes und der Länder (2010). *Demografischer Wandel in Deutschland, Heft 2, Auswirkungen auf Krankenhausbehandlungen und Pflegebedürftige im Bund und in den Ländern*. Online. Retrieved 2014/03/11, from http://www.statistikportal.de/statistik-portal/demografischer_wandel_heft2.pdf

Statistisches Bundesamt (2011). *Im Blickpunkt: Ältere Menschen in Deutschland der EU.* Online. Retrieved 2014/04/14, from https://www.destatis.de/DE/Publikationen/Thematisch/Bevoelkerung/Bevoelkerungsstand/BlickpunktAeltereMenschen1021221119004.pdf?__blob=publicationFile

Statistisches Bundesamt (2012a). *Alter im Wandel. Ältere Menschen in Deutschland und der EU.* Online. Retrieved 2014/04/14, from https://www.destatis.de/DE/Publikationen/Thematisch/Bevoelkerung/Bevoelkerungsstand/AlterimWandel0010017129004.pdf?__blob=publicationFile

Statistisches Bundesamt (2012b). *Alleinlebende in Deutschland – Ergebnisse des Mikrozensus 2011.* Online. Retrieved 2014/04/14, from https://www.destatis.de/DE/PresseService/Presse/Pressekonferenzen/2012/Alleinlebende/begleitmaterial_PDF.html

Steinke, F., Fritsch, T., & Silbermann, L. (2012a). Trust in Ambient Assisted Living (AAL): A systematic review of trust in automation and assistance systems. *International Journal on Advances in Life Sciences*, *4,* 77-88.

Steinke, F., Fritsch, T., Brem, D., & Simonsen, S. (2012b). Requirement of AAL systems – Older persons' trust in sensors and characteristics of AAL technologies. *Proceedings of the 5th International Conference on Pervasive Technologies Related to Assistive Environments, 15,* 1-6.

Steinke, F., Fritsch, T., Hertzer, A., Tautz, H., & Zickwolf, S. (2013). Expected reliability of everyday and Ambient Assisted Living technologies: Results from an online survey. *International Journal of Advanced Computer Science and Applications, 4(6),* 17-22.

Steinke, F., Bading, N., Fritsch, T., & Simonsen, S. (2014). Factors influencing trust in Ambient Assisted Living technology: A scenario-based analysis. *Gerontechnology, 12,* 81-100.

Steinke, F., Hertzer, A., & Fritsch, T. (2014). Experimental manipulation of reliability in ambient assisted living – an analysis of trust and intention to use. *International Journal of Human Factors and Ergonomics, 3(2)*, 122-147.

Steinke, F., Ingenhoff, A., & Fritsch, T. (2014). Personal remote assistance in Ambient Assisted Living experimental research of elderly people trust and intention to use. *International Journal of Human Computer Interaction, 30(7),* 560-574.

Szalma, J. L., & Taylor, G. S. (2011). Individual differences in response to automation: The five factor model of personality. *Journal of Experimental Psychology Applied, 17,* 71-96.

Turing, A. M. (1950). Computing machinery and intelligence. *Mind, 49,* 433-460.

United Nations (2013). *World Population Policies* (*2011)*. New York: Department of Economic and Social Affairs.

University Duisburg-Essen. *FoSIBLE Project*. Online. Retrieved 2014/04/14, from http://fosible.eu/

Van den Broek, G., Cavallo, F., & Wehmann, C. (2010). *AALIANCE Ambient Assisted Living Roadmap (Ambient Intelligence and Smart Environments).* Amsterdam: IOS Press.

Venkatesh, V., & Davis, F. D. (2000). A theoretical extension of the technology acceptance model: Four longitudinal field studies. *Management Science, 46(2),* 186-204.

Wälivaara, B.-M., Andersson, S., & Axelsson, K. (2009). Views on technology among people in need of health care at home. *International Journal of Circumpolar Health, 68(2),* 158-169.

Wandke, H. (2005). Assistance in human-machine interaction: A conceptual framework and a proposal for a taxonomy. *Theoretical Issues in Ergonomics Science, 6,* 129-155.

Warkentin, M., Gefen, D., Pavlou, P. A., & Rose, G. M. (2002). Encouraging citizen adoption of e-government by building trust. *Electronic markets*, *12*(3), 157-162.

Weyrich, C. (1999). *Information society technologies advisory group: Orientations for workprogramme 2000 and beyond*. Online. Retrieved 2013/10/22, from ftp://ftp.cordis.europa.eu/pub/ist/docs/istag-99-final.pdf

Wickens, C. D., & Dixon, S. R. (2005). *Is there a magic number 7 (to the minus 1)? The benefits of imperfect diagnostic automation: A synthesis of the literature*. Illinois: Aviation Research Lab.

Wilkowska, W., Gaul, S., & Ziefle, M. (2010). A Small but significant difference – The role of gender on acceptance of medical assistive technologies. In *Proceedings of the 6th Symposium of the Workgroup Human-Computer Interaction and Usability Engineering* (pp. 82-100), 4-5 November 2010 Klagenfurt, Austria. Heidelberg: Springer.

Wilkowska, W., & Ziefle, M. (2012). Privacy and data security in E-health: Requirements from the user's perspective. *Health Informatics Journal, 18(3),* 191-201.

Ziefle, M., & Schaar, A. K. (2011). Gender differences in acceptance and attitudes towards an invasive medical stent. *Electronic Journal of Health Informatics, 6(2),* e13.

Ziefle, M., Himmel, S., & Wilkowska, W. (2011). When your living space knows what you do. Acceptance of medical home monitoring by different technologies. In A. Holzinger, & K.-M. Simonic, (Eds.), *Information quality in e-Health. 7th Conference of the Workgroup Human-Computer Interaction and Usability Engineering of the Austrian Computer Society,* Graz, Austria (pp. 607-624). Heidelberg: Springer.

Ziefle, M., Klack, L., Wilkowska, W., & Holzinger, A. (2013). Acceptance of telemedical treatments: A medical professional point of view. In *Human Interface and the Management of Information. Information and Interaction for Health, Safety, Mobility and Complex Environments* (pp. 325-334). Heidelberg: Springer.

ACKNOWLEDGEMENTS

Im Folgenden möchte ich einigen Personen danken, ohne deren Unterstützung die vorliegende Arbeit nicht entstanden wäre. Zu aller erst gilt mein Dank meinem Doktorvater Prof. Dr. Hartmut Wandke, der mir durch sein ehrliches und konstruktives Feedback über die vergangenen vier Jahre die Fertigstellung dieser Arbeit ermöglicht hat und für dessen Vertrauen ich mich herzlichst bedanken möchte. Des Weiteren bedanke ich mich bei meinem Mentor und guten Freund Tobias Fritsch, der mich durch seine Beratung und Anleitung, besonders in den schwierigen Phasen am Anfang der Dissertationszeit, auf den richtigen Weg geführt hat. Ein weiterer Dank gilt meinem derzeitigen Chef und Group Chief Information Officer (CIO) der Allianz SE, Dr. Ralf Schneider, der durch die Förderung von jungen Absolventen innerhalb der Allianz IT die Etablierung des Dissertationsstipendiums erst ermöglicht hat. Durch die Verknüpfung von Forschung und Praxis wurde mir ein Berufseinstieg ermöglicht, den ich in anderen Unternehmen in dieser Form nicht erhalten hätte.

Darüber hinaus danke ich meinen Co-Autoren der vier in dieser Arbeit integrierten wissenschaftlichen Studien: Nicole Bading, Lina Silbermann, Svenja Simonsen, Alexander Ingenhoff und Andreas Hertzer für Ihre fortwährende Unterstützung und Hilfe. Des Weiteren möchte ich Kathrin Braulik, Johanna Foltz, Lena Funk, Daniel Brem, Jörg Heinze, Helmut Tautz und Simon Zickwolf danken, die mir während verschiedener Phasen meiner Dissertation bei inhaltlichen und organisatorischen Fragen hilfreich zur Seite standen. Meinem HR- Lieblingsteam sowie vieler Freunde und Kollegen bei der Allianz habe ich es zu verdanken, dass ich auch nach über fünf Jahren noch immer in München bin, da sie mein Leben dort erleichtert und bereichert haben. Besonderer Dank gilt hier Frederik Kerssenfischer. Christiane Neue, Rolf Kressner und Marcel Werner - der Berlin-Fraktion – möchte ich ebenfalls danken, dass sie mir im richtigen Moment immer wieder die Augen geöffnet und mir Mut zugesprochen haben, meine Ziele zu verfolgen, auch wenn es nicht der einfachste Weg war.

Mein spezieller Dank, den es nicht in Worten auszudrücken geht, gilt meinen Eltern Karin und Wolfgang, die mich in allen meinen Entscheidungen unterstützt haben und unterstützen - und mir zur richtigen Zeit immer mit Rat und Tat zur Seite stehen. Danke Euch beiden!

SUPPLEMENTS

Supplement A: List of publications

Supplement B: Overall references

Supplement A: List of publications

Steinke, F., Bading, N., Fritsch, T., & Simonsen, S. (2014). Factors influencing trust in Ambient Assisted Living technology: A scenario-based analysis. *Gerontechnology, 12,* 81-100.

Steinke, F., Hertzer, A., & Fritsch, T. (2014). Experimental manipulation of reliability in ambient assisted living – an analysis of trust and intention to use. *International Journal of Human Factors and Ergonomics, 3(2)*, 122-147.

Steinke, F., Ingenhoff, A., & Fritsch, T. (2014). Personal remote assistance in Ambient Assisted Living experimental research of elderly people trust and intention to use. *International Journal of Human Computer Interaction, 30(7),* 560-574.

Brem, D., Fritsch, T., Steinke, F., & Kerssenfischer, F. (2013). Towards influencing factors on business models of ambient assisted living systems. In *the Fifth International Conference on eHealth, Telemedicine, and Social Medicine* (pp. 290- 295). Nice, France.

Fritsch, T., Brem, D., Steinke, F., Muhl-Lassen, A., & Kerssenfischer, F. (2013). Social network sites for elderly people - A critical analysis of established German-speaking online platforms. *Journal of Economics, Business and Management, 1(2),* 182-186.

Steinke, F., Fritsch, T., Hertzer, A., Tautz, H., & Zickwolf, S. (2013). Expected reliability of everyday and Ambient Assisted Living technologies: Results from an online survey. *International Journal of Advanced Computer Science and Applications, 4(6),* 17-22.

Fritsch T, Steinke, F., & Brem, D. (2012). Analysis of elderly persons' social network: Need for an appropriate online platform. In *Proceedings of the Sixth International AAAI Conference on Weblogs and Social Media* (pp. 463-466). Dublin, Ireland.

Steinke, F., Fritsch, T., Brem, D., & Simonsen, S. (2012). Requirement of AAL systems – Older persons' trust in sensors and characteristics of AAL technologies. *Proceedings of the 5th International Conference on Pervasive Technologies Related to Assistive Environments, 15,* 1-6.

Steinke, F., Fritsch, T., Brem, D., & Simonsen, S. (2012). Purchase intention of Ambient Assisted Living technology - Results from a German perspective. In *IADIS International Conference e-Health 2012* (pp. 146-155). Lisbon, Portugal.

Steinke, F., Fritsch, T., & Silbermann, L. (2012). Trust in Ambient Assisted Living (AAL): A systematic review of trust in automation and assistance systems. *International Journal on Advances in Life Sciences, 4,* 77-88.

Steinke, F., Fritsch, T., & Silbermann, L. (2012). A systematic review of trust in automation and assistance systems for older persons' overall requirements. eTELEMED 2012. *The Fourth International Conference on eHealth, Telemedicine, and Social Medicine* (pp. 155-163). Valencia, Spain.

Kaiser, M. , Kerssenfischer, F., Steinke, F., & Fritsch, T., (2011). Quality improvement models for business process change - A german case study. *Lecture Notes in Business Information Processing, 97(1),* 78-91.

Supplement B: Overall references

Abe, G., & Richardson, J. (2006). Alarm timing, trust and driver expectation for forward collision warning systems. *Applied Ergonomics, 37,* 577-586.

Afentakis, A., & Maier, T. (2010). Projektionen des Personalbedarfs und -angebots in Pflegeberufen bis 2025. *Wirtschaft und Statistik, 11,* 990-1002.

Ambient Assisted Living Joint Programme (2013). *Catalogue of Projects 2013.* Online. Retrieved 2013/10/28, from http://www.aal-europe.eu/wp-content/uploads/2013/09/AALCatalogue2013_Final.pdf

Ambient Assisted Living Joint Programme (2010). *Definition of end-users in the AAL Joint Programme.* Online. Retrieved 2013/07/01, from http://www.aal-europe.eu/get-involved/i-am-a-user-2/

ASIMO (2013). *Asimo The World's Most Advanced Humanoid Robot.* Online. Retrieved 2013/05/20, from: http://asimo.honda.com/inside-asimo/

Autonomous learning agents for decentralised data and information networks (2013). *Supporting the self-management of dementia at home.* Online. Retrieved 2013/10/28, from http://www.aladdin-project.eu/

Awad, N. F., & Ragowsky, A. (2008). Establishing trust in electronic commerce through online word of mouth: An examination across genders. *Journal of Management Information Systems*, *24(4),* 101-121.

Backes, G. M., & Clemens, W. (2008). *Lebensphase Alter: Eine Einführung in die sozialwissenschaftliche Alternsforschung.* Weinheim: Beltz Juventa.

Bagheri, N., & Jamieson, G. (2004). The impact of context-related reliability on automation failure detection and scanning behavior systems. In *Proceedings of the 2004 IEEE International Conference on Man and Cybernetics* (pp. 212-217), 10-13 October Toronto, Canada.

Bahner, J. E., Hueper, A.-D., & Manzey, D. (2008). Misuse of automated decision aids: Complacency, automation bias and the impact of training experience. *International Journal of Human-Computer Studies, 66,* 688-699.

Bailey, N. R., & Scerbo, M. W. (2007). Automation-induced complacency for monitoring highly reliable systems: The role of task complexity, system experience, and operator trust. *Theoretical Issues in Ergonomics Science, 8(4),* 321-348.

Bainbridge, W. A., Hart, J., Kim, E. S., & Scassellati, B. (2008). The effect of presence on human-robot interaction. In *Proceedings of the 17th IEEE Symposium on Robot and Human Interactive Community* (pp. 701-706)*,* 1-3 August 2008 Munich, Germany.

Baltes, M. M. (1998). The psychology of the oldest-old: The fourth age. *Current Opinion Psychiatry, 11(4),* 411-415.

Baltes, P. B. (1997). On the incomplete architecture of human ontogeny: Selection, optimization, and compensation as foundation of developmental theory. *American Psychologist, 52(4),* 366-380.

Baltes, P. B., Smith, J. (1999). Multilevel and systemic analyses of old age: Theoretical and empirical evidence for a fourth age. In V. L. Bengtson, & K. W. Schaie (Eds.), *Handbook of Theories of Aging* (pp. 153-173). New York: Springer.

Baltes, P. B., & Smith, J. (2003). New frontiers in the future of aging: From successful aging of the young old to the dilemmas of the fourth age. *Gerontology, 49(2),* 123-135.

Becks, T., Dehm, J., & Eberhardt, B. (2007). *Ambient Assisted Living. Neue "intelligente""Assistenzsysteme für Prävention, Homecare und Pflege.* Frankfurt am Main: Deutsche Gesellschaft für Biomedizinische Technik im VDE.

Becks, T., Eberhardt, B., Heusinger, S., Pongratz, S., & Stein, J. (2010). *Intelligente Heimvernetzung Komfort – Sicherheit – Energieeffizienz – Selbstbestimmung.* Online. Retrieved 2013/06/06, from http://www.vde.com/de/Institut/QuerschnittstechnologienIntelligenteHeimvernetzung/Documents/Posipap-Heimvernetzung_Web[1].pdf

Belbachir, A. N., Litzenberger, M., Schraml, S., Hofstatter, M., Bauer, D., Schon, P., Humenberger, M., Sulzbachner, C., Lunden, T., & Merne, M. (2012). CARE: A dynamic stereo vision sensor system for fall detection. *Circuits and Systems (ISCAS),* 731-734.

Bestic™ (2013). *Bestic™ Independence, integrity, dignity and self-confidence.* Online. Retrieved 2013/05/20, from http://www.bestic.se/en/home/

BITKOM (2009). *60 Prozent der Deutschen über 65 Jahre wollen Telemedizin nutzen.* Online. Retrieved 2014/07/22, from http://www.bitkom.org/de/presse/62013_59050.aspx

Blazescape (2012). *Blazescape*. Online. Retrieved 2013/05/20, from http://www.blazescape.co.uk/facts.php

Bliss, J. P., & Dunn, M. C. (2000). Behavioural implications of alarm mistrust as a function of task workload. *Ergonomics, 43,* 1283-1300.

Blomqvist, K. (1997). The many faces of trust. *Scandinavian Journal of Management, 13(3),* 271-286.

BMBF/VDE Innovationspartnerschaft AAL (2012). *Ambient Assisted Living – ein Markt der Zukunft: Potenziale, Szenarien, Geschäftsmodelle.* Berlin: VDE.

Bridge, C., Davy, L., Judd, B., Flatau, P., Morris, A., & Phibbs, P. (2011). *Age-specific housing and care for low to moderate income older people - AHURI Final Report No. 174.* Online. Retrieved 2013/07/01, from http://www.be.unsw.edu.au/sites/default/files/upload/research/centres/cf/publications/ahuriprojectreports/AHURI_Final_Report_No174.pdf

Buck, E., & Bierhoff, H.-W. (1986). Verlässlichkeit und Vertrauenswürdigkeit: Skalen zur Erfassung des Vertrauens in eine konkrete Person. *Zeitschrift für Differentielle und Diagnostische Psychologie, 7(4),* 205-223.

Bullinger, M., Kirchberger, I., & Ware, J. (1995). Der deutsche SF-36 Health Survey Übersetzung und psychometrische Testung eines krankheitsübergreifenden Instruments zur Erfassung der gesundheitsbezogenen. *Journal of Public Health, 3(1),* 21-36.

Bundesministerium des Innern (2011). *Demografiebericht: Bericht der Bundesregierung zur demografischen Lage und künftigen Entwicklung des Land.* Rostock: Publikationsversand der Bundesregierung.

Bundesministerium für Bildung und Forschung (2008). *AAL. Altersgerechte Assistenzsysteme für ein gesundes und unabhängiges Leben. Ambient Assisted Living.* Online. Retrieved 2013/07/27, from http://www.aal-deutschland/deutschlandl-faltblatt

Bundesministerium für Bildung und Forschung (2009). *Assistenzsysteme im Dienste des älteren Menschen: Steckbriefe für ausgewählte Projekte in der BMBF Fördermaßnahme, Altersgerechte Assistenzsysteme für ein gesundes und unabhängiges Leben – AAL.* Online. Retrieved 2012/04/14, from https://ssl.vdivde-it.de/aaljp-transnationaler-informationstag/europa/dokumente/steckbriefsammlung-aal-call1_v4.pdf

Bundesministerium für Familie, Senioren Frauen und Jugend (2010). *Sechster Bericht zur Lage der älteren Generation in der Bundesrepublik Deutschland Altersbilder in der Gesellschaft.* Online. Retrieved 2014/07/23, from http://www.bmfsfj.de/RedaktionBMFSFJ/Abteilung3/Pdf-Anlagen/bt-drucksache-sechster-altenbericht,property=pdf,bereich=bmfsfj,sprache=de,rwb=true.pdf

Bundesstelle für Flugunfalluntersuchung (2004). *Untersuchungsbericht AX001-1-2/02 (Flugunfall Überlingen).* Online. Retrieved 2012/11/12, from http://www.bfu-web.de/nn_41670/DE/Publikationen/Untersuchungsberichte/2002/Bericht__02__AX001-1-2,templateId=raw,property= publicationFile.pdf/Bericht_02_AX001-1-2.pdf

Bundesministerium für Gesundheit (2013). *Pflegebedürftigkeit.* Online. Retrieved 2012/04/14, from http://www.bmg.bund.de/pflege/pflegebeduerftigkeit/pflegebeduerftigkeit.html

Bundesministerium für Gesundheit (2013). *Pflegestufen.* Online. Retrieved 2012/04/14, from http://www.bmg.bund.de/pflege/pflegebeduerftigkeit/pflegestufen.html

Callon, M. (2009). Some elements of a sociology of translation: Domestication of the scallops and the fishermen of St Brieuc Bay. In J. Law (Ed.), *Power, action and belief: A new sociology of knowledge? Sociological review monograph* (pp. 196-233). London: Routledge and Kegan Paul.

Calnan, M., Montaner, D., & Horne, R. (2005). How acceptable are innovative health-care technologies? A survey of public beliefs and attitudes in England and Wales. *Social Science and Medicine, 60,* 1937-1948.

Caroll, J. M. (2000). Five reasons for scenario-based design. *Interacting with Computers,13,* 43-60.

Carter, L., & Bélanger, F. (2005). The utilization of e-government services: Citizen trust, innovation and acceptance factors. *Information Systems Journal, 15*, 5-25.

Castaldo, S., Premazzi, K., & Zerbini, F. (2010). The meaning(s) of trust. A content analysis on the diverse conceptualizations of trust in scholarly research on business relationships. *Journal of Business Ethics, 96(4),* 657-668.

Chaumon, M.-E. B., Michel, C., Bernard, F. T., & Croisile, B. (2014). Can ICT improve the quality of life of elderly adults living in residential home care units? *Behaviour and Information Technology, 33,* 574-590.

Chaumon, M.-E. B., Michel, C., Tarpin Bernard, F., & Croisile, B. (2014). Can ICT improve the quality of life of elderly adults living in residential home care units? From actual impacts to hidden artefacts. *Behaviour & Information Technology, 33(6),* 574-590.

Chen, K., & Chan, A. H. (2014). Gerontechnology acceptance by elderly Hong Kong Chinese: A senior technology acceptance model (STAM). *Ergonomics, 57,* 1-18.

Chen, Y., & Sun, Y. (2003). Age differences in financial decision-making: Using simple heuristics. *Educational Gerontology, 29(7),* 627-635.

Chiriac, S., & Rosales, B. (2012). An AAL Monitoring System for activity recognition. Results from the first evaluation stages. In R. Wichert, & B. Eberhard (Eds.), *Ambient Assisted Living* (pp. 15-28). Heidelberg: Springer.

Chugh, J. S., & Caird, J. K. (1999). In-Vehicle Train Warnings (ITW): The Effect of reliability and failure type on driver perception response time and trust. In *Proceedings of the Human Factors and Ergonomics Society Annual Meeting* (pp. 1012-1016)*,* September 1999 Houston, TX.

Compagna, D., Derpman, S., Helbig, T., & Shire, K. (2011). Pflegenotstand technisch lösbar? Funktional-partizipative Technikentwicklung im Pflegesektor. *Technik-Folgen-abschätzung – Theorie und Praxis, 20(1),* 71-75.

Costa, A., Andrade, F., Novais, P., & Simoes, R. (2012). Privacy and data protection in elderly healthcare: Threats and legal warranties. In *Proceedings of the Sixth International Workshop on Juris-informatics* (pp. 7-20).

Coughlin, J. F., D'Ambrosio, L. A., Reimer, B., & Pratt, M. R. (2007). Older adult perceptions of smart home technologies: Implications for research, policy and market innovations in healthcare. In *Proceedings of the Engineering in Medicine and Biology Annual Conference IEEE* (pp. 1810-1815), 2007 Lyon, France.

Coughlin, J. F., Lau, J., Ambrosio, L., & Reimer, B. (2009). Adult children's perceptions of intelligent home systems in the care of elderly parents. In *Proceedings of the 3rd International Convention on Rehabilitation Engineering and Assistive Technology,* 2009 New York, USA.

Daley, D. T. (2010). *Reliability assessment: A guide to aligning expectations, practices and performance.* New York: Transatlantic Publishers.

Dassonville, I., Jolly, D., & Desodt, A. M. (1996). Trust between man and machine in a teleoperation system. *Reliability Engineering and System Safety, 53(3),* 319-325.

Davis, F. D. (1986). *A technology acceptance model for empirically testing new end-user information systems: Theory and results.* PhD thesis, Cambridge Massachusetts Institute of Technology, United States.

Davis, F. D. (1989). Perceived usefulness, perceived ease of use, and user acceptance of information technology. *MIS Quarterly, 13,* 319-340.

Davis, F. D., Bagozzi, R. P., & Warshaw, P. R. (1989). User acceptance of computer technology: A comparison of two theoretical models. *Management Science, 35(8),* 982-1003.

de Vries, P., Midden, C., & Bouwhuis, D. (2003). The effects of errors on system trust, self-confidence, and the allocation of control in route planning. *International Journal of Human-Computer Studies, 58,* 719-735.

Demeris, G., & Hensel, B. K. (2008). Technologies for an aging society: A systematic review of "Smart Home" applications. *Yearbook of Medical Informatics, 1,* 33-40.

Deutch, M. (1958). Trust and suspicion. *Journal of Conflict Resolution,* 2, 265-279.

Deutch, M. (1960). The effect of motivational orientation upon trust and suspicion. *Human Relations, 13,* 123-139.

Dijkstra, J. J., Liebrand, W. B. G., & Timminga, E. (1998). Persuasiveness of expert systems. *Behaviour and Information Technology, 17(3),* 155-163.

Dixon, S. R., & Wickens, C. D. (2006). Automation reliability in unmanned aerial vehicle control: A reliance-compliance model of automation dependence in high workload. *Human Factors, 48,* 474-486.

Dunn, D. S. (2009). *Research methods for social psychology.* Malden, MA: Wiley-Blackwell.

Dzindolet, M. T., Beck, H. P., Pierce, L. G., & Dawe, L. A. (2001). *A framework of automation use.* Aberdeen Proving Ground, MD: Army Research Laboratory.

Dzindolet, M. T., Pierce, L. G., Beck, H. P., & Dawe, L. A. (2002). The perceived utility of human and automated aids in a visual detection task. *Human Factors, 44,* 79-94

Dzindolet, M. T., Peterson, S. A., Pomranky, R. A., Pierce, L. G., & Beck, H. P. (2003). The role of trust in automation reliance. *International Journal of Computer Studies, 58,* 697-718.

Dzindolet, M. T., Pierce, L. G., Beck, H. P., Dawe, L. A., & Anderson, B. W. (2001). Predicting misuse and disuse of combat identification systems. *Military Psychology, 13(3),* 147-164.

Elsayed, A. (2012). *Reliability engineering - Wiley series in systems engineering and management.* New Jersey: John Wiley and Sons.

Ezer, N., Fisk, A. D., & Rogers, W. A. (2008). Age-related differences in reliance behavior attributable to costs within a human-decision aid system. *Human Factors, 50,* 853-863.

Ferraro, K. F. (1980). Self-Ratings of health among the old and the old-old. *Journal of Health and Social Behavior, 21(4),* 377-383.

Field, A., & Hole, G. (2011). *How to design and report experiments*. Los Angeles: Sage.

Field, D., & Minkler, M. (1998) Continuity and change in social support between young-old and old-old or very-old age. *Journal of Gerontology, 43(4),* 100-106.

Fishbein, M., & Ajzen, I. (1975). *Belief, attitude, intention and behavior: An introduction to theory and research.* Massachusetts: Addison-Wesley.

Floeck, M., & Litz, L. (2008). *Integration of home automation technology into an assisted living concept. Assisted Living Systems - models, architectures and engineering approaches*. Online. Retrieved 2014/07/22, from http://drops.dagstuhl.de/opus/volltexte/2008/1459/pdf/07462.FloeckMartin.Paper.1459.pdf

Fox, J. E., & Boehm-Davis, D. A. (1998). Effects of age and congestion information accuracy of advanced traveler information systems on user trust and compliance. *Transportation Research Record, 1621,* 43-49.

Fraunhofer ISST (2011). *Zuhause Daheim: Das Projekt JUTTA*. Online. Retrieved 2012/11/12, from http://www.inhaus.fraunhofer.de/Geschaeftsfelder/Health-und-Care/jutta.jsp

Fraunhofer ISST (2013). *Smart and Independent Living for the Elderly – SMILEY: Projektabschlussbericht.* Online. Retrieved 2013/04/14, from http://www.isst.fraunhofer.de/content/dam/isst/de/documents/Forschungsnews/Fraunhofer-ISST_SMILEY-Schlussbericht_1.1.pdf

Freedy, A., de Visser, E., Weltman, G., & Coeyman, N. (2007). Measurement of trust in human-robot collaboration. In *Proceedings of the 2007 International Conference on Collaborative Technologies and Systems* (pp. 106-114), 25 May 2007 Orlando, FL.

Gao, J., Lee, J. D., & Zhang, Y. (2006). A dynamic model of interaction between reliance on automation and cooperation in multi-operator multi-automation situations. *International Journal of Industrial Ergonomics, 36,* 511-526.

Gefen, D., Karahanna, E., Straub, D. W. (2003). Trust and TAM in online shopping: An integrated model. *MIS Quarterly, 27(1),* 51-90.

Geiger, M. (2009). *Pflege in einer alternden Gesellschaft: Projekt - Perspektiven auf den demografischen Wandel.* Saarbrücken: Institut für Sozialforschung und Sozialwissenschaft e.V..

Georgieff, P. (2008). *Ambient Assisted Living - Marktpotentiale IT-unterstützter Pflege für ein selbstbestimmtes Altern.* Stuttgart: MFG Stiftung Baden-Württemberg.

Gersch, M., & Liesenfeld, J. (2012). *AAL- und E-Health-Geschäftsmodelle: Technologie und Dienstleistungen im demografischen Wandel und in sich verändernden Wertschöpfungsarchitekturen.* Wiesbaden: Gabler.

Gersch, M., Lindert, R., & Hewing, M. (2010). *AAL-business models: Different prospects for the successful implementation of innovative services in the primary and secondary healthcare market*. Online. Retrieved 2012/11/12, from http://www.aaliance.eu/public/oldstuff/aaliance-conference-1/papers-and-posters/8_2_fu-berlin

Ghazizadeh, M., Peng, Y., Lee, J. D., & Boyle, L. N. (2012). Augmenting the technology acceptance model with trust: Commercial drivers' attitudes towards monitoring and feedback. *Proceedings of the Human Factors and Ergonomics Society Annual Meeting, 56,* 2286-2290.

Giesecke, S., Hull, J., Schmidt, S., Strese, H., Weiß, C., & Baumgarten, D. (2005). *Ambient Assisted Living*. Country Report Germany.

Goldberg, L. R. (1990). An alternative "description of personality": The big-five factor structure. *Journal of personality and social psychology, 59(6),* 1216-1229.

Grauel, J., & Spellerberg, A. (2008). Wohnen mit Zukunft - Soziologische Begleitforschung zu Assisted Living-Projekten. In E. Maier, & P. Roux, (Eds.), *Seniorengerechte Schnittstellen zur Technik: Zusammenfassung der Beiträge zum Usability Day VI* (pp. 36-43). Lengerich: Pabst Science Publ.

Grünig, R., & Kühn, R. (2009). *Successful decision-making: A systematic approach to complex problems.* Berlin: Springer.

Harrefors, C., Axelsson, K., & Sävenstedt, S. (2010). Using assistive technology services at differing levels of care: Healthy older couples' perceptions. *Journal of Advanced Nursing, 66(7),* 1523-1532.

Heerink, M., Kröse, B., Evers, V., & Wielinga, B. (2012). Assessing acceptance of assistive social agent technology by older adults: The almere model. *International Journal of Social Robotics, 2(4),* 361-375.

Heinze, R. G., & Ley, C. (2009). *Abschlussbericht des Forschungsprojektes „Vernetztes Wohnen. Ausbreitung, Akzeptanz und nachhaltige Geschäftsmodelle".* Online. Retrieved 2012/11/12, from http://www.sowi.rub.de/mam/content/heinze/heinze/abschlussbericht_vernetzteswohnen.pdf

Hellman, R. (2012). *Mylife -Multimedia technology to support independence for and participation by people with dementia (2011-202).* Online. Retrieved 2013/10/28, from http://www.karde.no/MYLIFE_english.html

Hendrick, H. W., & Kleiner, B. M. (2001). *Macroergonomics: An introduction to work system design.* Santa Monica, CA: Human Factors and Ergonomics Society.

Hertzer, A. (2013). *Zuverlässigkeit als Einflussfaktor für Vertrauen älterer Personen in häusliche Unterstützungstechnologien*. Diploma thesis. Professur für Wirtschafts-informatik und Management Support, Universität Augsburg.

Herzberg, F., Mausner, B., & Snyderman, B. B. (1959). *The motivation to work (2nd ed.).* New York: John Wiley.

Heusinger, W. (2005). *Das intelligente Haus - Entwicklung und Bedeutung für die Lebensqualität.* Frankfurt am Main: Peter Lang.

Heydenbluth, C. (2013). *To trust or not to trust: Wann vertrauen Menschen in technologische Systeme?* Bachelor thesis, Humboldt-Universität zu Berlin, Germany.

Hilbert, J., Scharfenorth, K., & Haberle, J. (1999). *Vom virtuellen Altenheim zu TESS inkontakt. Erfahrungen aus einem Entwicklungs- und Erprobungsprojekt für mehr Lebensqualität im Alter.* Online. Retrieved 2014/07/23, from http://iatinfo.iatge.de/aktuell/veroeff/ds/hilbert99a.pdf

Hinkelmann, K., & Kempthorne, O. (2007). *Design and analysis of experiments: Introduction to experimental design.* New Jersey: John Wiley and Sons.

Ho, G., Kiff, L. M., Plocher, T., & Haigh, K. Z. (2005). A model of trust and reliance of automation technology for older users. *AAAI Fall Symposium on Caring Machines* (pp. 45-50), 2005 Menlo Park, CA.

Ho, G., Wheatley, D., & Scialfa, C. T. (2005). Age differences in trust and reliance of a medication management system. *Interacting with Computers, 17,* 690-710.

Hoff, K., & Bashir, M. (2013). A theoretical model for trust in automated systems. In *CHI'13 Extended Abstracts on Human Factors in Computing Systems* (pp. 115-120), New York, USA.

Holland, D. C. P., & Lockett, P. A. G. (2012). Business trust and the formation of virtual organizations. *Journal of Management Information Systems, 16(2),* 91-112.

Horst, M., Kuttschreuter, M., & Gutteling, J. M. (2007). Perceived usefulness, personal experiences, risk perception and trust as determinants of adoption of e-government services in the Netherlands. *Computers in Human Behavior, 23(4),* 1838-1852.

Hu, P. J., Chau, P. Y. K., Liu Sheng, O. R., & Yan Tam, K. (1999). Examining the technology acceptance model using physician acceptance of telemedicine technology. *Journal of Management Information Systems, 16(2),* 91-112.

Hwang, Y. (2009). The impact of uncertainty avoidance, social norms and innovativeness on trust and ease of use in electronic customer relationship management. *Electronic Markets, 19(2-3),* 89-98.

Hughes, J. S., Rice, S., Trafimow, D., & Clayton, K. D. (2009). The automated cockpit: A comparison of attitudes towards human and automated pilots. *Transportation Research, 12(5),* 428-439.

Institut für Sozialforschung und Sozialwirtschaft e.V. (2010). Ausgewählte Demografieprojekte aus den Forschungs- und Entwicklungsprogrammen des Bundesministeriums für Bildung und Forschung, Innovationen mit Dienstleistungen und Arbeiten – Lernen – Kompetenzen entwickeln Innovationsfähigkeit in einer modernen Arbeitswelt. In *5. Demografie-Kongress: Der Staat im Wandel Generationenpolitik zwischen Fürsorge, Vorsorge und Gewährleistung,* 6-7 September 2010 Berlin, Germany.

Institut für Sozialforschung und Sozialwirtschaft e.V. (2011). *Technologie und Dienstleistungen im demografischen Wandel.* Online. Retrieved 2014/07/24, from http://partner.vde.com/bmbf-aal/Publikationen/Fachbeitraege/extern/Documents/ /Ergebnisbrosch%C3%BCre_BMBF_Metavorhaben.pdf

Jasemian, Y. (2008). Elderly comfort and compliance to modern telemedicine system at home. In *Proceedings of the Second International Conference on Pervasive Computing*

Technologies for Healthcare (pp. 60-63), 30 January – 1 February 2008 Tampere, Finland.

Jian, J.-Y., Bisanz, A. M, & Drury, C. G. (2000). Foundations for an empirically determined scale of trust in automated systems. *International Journal of Cognitive Ergonomics, 4,* 53-71.

Jiang, X., et al. (2004). Measurement of human trust in a hybrid inspection system based on signal detection theory measures. *International Journal of Industrial Ergonomics, 34,* 407-419.

Jonsson, A., & Bergqvist, A. (2013). *Dödsbränder i Sverige - Kvalitetsgranskning av MSB:s Dödsbrandsdatabas.* Online. Retrieved 2014/07/23, from http://www.vfdb.de/download/DoedsbraenderSverige.pdf

Jung, M.-L., & Loria, K. (2010). Acceptance of swedish e-health services. *Journal of Multidisciplinary Healthcare, 3,* 55-63.

Kaiser, H. F., Rice, J. (1974). Little Jiffy Mark IV. *Educational and Psychological Measurement, 34(1),* 111-117.

Kano, N., Seraku, N., Takahashi, F., & Tsuji, S. (1984). Attractive quality and must-be quality. *The Journal of the Japanese Society for Quality Control, 14(2),* 39-48.

Kantowitz, B. H., Hanowski, R. J., & Kantowitz, S. C. (1997). Driver acceptance of unreliable traffic information in familiar and unfamiliar settings. *Human Factors, 39,* 164-176.

Karrer, K., Glaser, C., Clemens, C., & Bruder, C. (2009). Technikaffinität erfassen – der Fragebogen TA-EG. In A. Lichtenstein, C. Stößel, & C. Clemens (Eds.), *Der Mensch im Mittelpunkt technischer Systeme* (pp. 196-201). Düsseldorf: VDI Verlag GmbH.

Keller, A., & Rice, S. (2010). System-wide versus component-specific trust using multiple aids. *The Journal of General Psychology, 137,* 114-128.

King, W. R., & He, J. (2006). A meta-analysis of the technology acceptance model. *Information and Management, 43(6),* 740-755.

Kornmeier, K. (2009). *Determinanten der Endkundenakzeptanz mobilkommunikations-basierter Zahlungssysteme - Eine theoretische und empirische Analyse.* PhD thesis, University Duisburg-Essen, Germany.

Kung, A., & Jean-Bart, B. (2010). Making AAL platforms a reality. *Ambient Intelligence Lecture Notes in Computer Science, 6439,* 187-196.

Latour, B. (1987). *Science in action: How to follow scientists and engineers through society.* Cambridge: Harvard University Press.

Lee, J. D., & Moray, N. (1992). Trust, control strategies and allocation of function in human-machine systems. *Ergonomics, 35,* 1243-1270.

Lee, J. D., & Moray, N. (1994). Trust, self-confidence, and operators' adaptation to automation. *International Journal of Human-Computer Studies, 40,* 153-184.

Lee, J. D., & See, K. A., (2004). Trust in automation: Designing for appropriate reliance. *Human Factors, 46,* 50-80.

Lees, M. N., & Lee, J. D. (2007). The influence of distraction and driving context on driver response to imperfect collision warning systems. *Ergonomics, 50(8),* 1264-1286.

Lee, J. D., Gore, B. F., & Campbell. J. L. (1999). Display alternatives for in-vehicle warning and sign information: Message style, location, and modality. *Transportation Human Factors, 1(4),* 347-377.

Legris, P., Ingham, J., & Collerette. P. (2003). Why do people use information technology? A critical review of the technology acceptance model. *Information and Management, 40(3),* 191-204.

Leopold, G. (1985). Will 'Smart House' provide shelter for high-tech firms? *Electronics, 58(26),* 45-46.

Lewandowsky, S., Mundy, M., & Tan, G. P. A. (2000). The dynamics of trust: Comparing humans to automation. *Journal of Experimental Psychology, 6(2),* 104-123.

Luarn, P., & Lin, H. H. (2005). Toward an understanding of the behavioral intention to use mobile banking. *Computers in Human Behavior*, *21(6),* 873-891.

Luhmann, N. (1979). *Trust and Power.* New York: Wiley.

Ma, Q., & Liu, L. (2004). The technology acceptance model: A meta-analysis of empirical findings. *Journal of Organizational and End User Computing, 16(1),* 59-72.

Madhavan, P., & Wiegmann, D. A. (2007). Similarities and differences between human–human and human–automation trust: An integrative review. *Theoretical Issues in Ergonomics Science, 8(4),* 277-301.

Madhavan, P., Wiegmann, D. A., & Lacson, F. C. (2006). Automation failures on tasks easily performed by operators undermine trust in automated aids. *Human Factors, 48,* 241-256.

Masalonis, A. J., & Parasuraman, R. (1999). Trust as a construct for evaluation of automated aids: Past and future theory and research. *Proceedings of the Human Factors and Ergonomics Society Annual Meeting, 43(3),* 184-187.

Masalonis, A. J., Duley, J. A., Galster, S. M., Castano, D. J., Metzger, U., & Parasuraman, R. (1998). Air traffic controller trust in a conflict probe during free flights. In *Proceedings*

of the Human Factors and Ergonomics Society Annual Meeting, 5-9 October 1998, Santa Monica, CA.

McCloskey, D. W. (2006). The importance of ease of use, usefulness, and trust to online consumers: An examination of the technology acceptance model with older customers. *Journal of Organizational and End User Computing, 18*(3), 47-65.

McGuirl, J. M., & Sarter, N. B. (2006). Supporting trust calibration and the effective use of decision aids bypresenting dynamic system confidence information. *Human Factors, 48(4),* 656-665.

McKnight, H. D., Cummings, L. L., & Chervany, N. L. (1998). Initial trust formation in new organizational relationships. *The Academy of Management Review, 23(3),* 473-490.

Merritt, S. M., & Ilgen, D. R. (2008). Not all trust is created equal: Dispositional and history-based trust in human automation interactions. *Human Factors, 50,* 194-210.

Merritt, S. M., Heimbaugh, H., LaChapell, J., & Lee, D. (2013). I trust it, but I don't know why: Effects of implicit attitudes toward automation on trust in an automated system. *Human Factors, 55(3),* 520-534.

Miles, I. (1990). <Shift> <Control>,...<Home>? A Response to Robins and Cornford. *Futures, 22(8),* 880-885.

Miller, C. A. (2005). Trust in adaptive automation: The role of etiquette in tuning trust via analogic and affective methods. In *Proceedings of the First International Conference on Augmented Cognition,* 22-27 July 2005 Las Vegas, NV.

Miller, C. A., Haigh, K., & Dewing, W. (2002). First, cause no harm: Issues in building safe, reliable and trustworthy elder care systems. In *Proceedings of the AAAI-02 Workshop Automation as Caregiver* (pp. 80-84). Emonton, Alberta, Canada.

Mohammed, M., Bhattacharjee, A., & Kwak, J. (2005). Remote Assistance. United States Patent No.: US 6,973,482 B2, Date of Patent: Dec. 6, 2005.

Montague, E. N. H. (2010a), Patient source of learning about health technologies and ratings of trust in technologies used in their care. *Ergonomics, 53(11),* 1302-1310.

Montague, E. N. H. (2010b). Validation of a trust in medical technology instrument. *Applied Ergonomics*, *41(16),* 812-821.

Montague, E. N. H., & Kleiner, B. M. (2009). Using variance analysis to detect mismatches in role expectations in patient physician interactions in obstetric work systems. Paper presented at the *2009 International Ergonomics Association,* Beijing, China, 2009.

Montague, E. N. H., Kleiner, B. M., & Winchester III, W. W. (2009). Empirically understanding trust in medical technology. *International Journal of Industrial Ergonomics, 39(4),* 628-634.

Montague, E. N. H., Winchester III, W. W., & Kleiner, B. M. (2010). Trust in medical technology by patients and healthcare providers in obstetric work systems. *Behaviour and Information Technology, 29,* 541-554.

Moray, N., Inagaki, T., & Itoh, M. (2000). Adaptive automation, trust, and self-confidence in fault management of time-critical tasks. *Journal of Experimental Psychology, 6,* 44-58.

Moser-Siegmeth, V., & Aumayr, G. (2011). *Alter und Technik, Theorie und Praxis.* Wien: Facultas.

Muir, B. M. (1987). Trust between humans and machines, and the design of decision aids. *International Journal of Man Machine Studies, 27,* 527-539.

Muir, B. M. (1994). Trust in automation: Part I. Theoretical issues in the study of trust and human intervention in automated systems. *Ergonomics, 37(11),* 1905-1922.

Muir, B. M., & Moray, N. (1996). Trust in automation: Part II. Experimental studies of trust and human intervention in a process control simulation. *Ergonomics, 39(3),* 429-460.

Naresky, J. J. (1970). Reliability definitions. *IEEE Transactions On Reliability, 19(4),* 198-200.

National Transportation Safety Board (1997). *Grounding of the panamanian passenger ship royal majesty on rose and crown shoal near Nantucket.* Online. Retrieved 2014/04/14, from www.ntsb.gov/doclib/reports/1997/mar9701.pdf

Neugarten, B. L. (1974). Age groups in american society and the rise of the young-old. *The Annals of the American Academy of Politica and Social Science, 415(1),* 187-198.

Neyedli, H. F., Wang, L., Jamieson, G. A., & Hollands, J. G. (2010). Evaluating reliance on combat identification systems: The role of reliability feedback. In D. H. Andrews, R. P. Herz, & M. B. Wolf, (Eds.), *Human factors issues in combat identification* (pp. 249-264). Burlington: Ashgate.

Nikolaos, B. (2014). *Managing older people social relationships for better communication, activation and interaction.* Online. Retrieved 2014/04/14, from http://www.elderspaces.eu/

Noorderhaven, N. G. (1992). Trust and inter-firm relations. In *Proceedings of the 1992 EAEPE Conference,* 4-6 November 1992 Paris, France.

Osl, P., Benz, A., & Österle, H. (2010). Dienstleistungen für Independent Living: Kundenanforderungen und Optionen für die Angebotsgestaltung. In *Tagungsband Ambient Assisted Living - 3. Deutscher Kongress mit Ausstellung.* Berlin: VDE.

Parasuraman, R., & Manzey, D. (2010). Complacency and bias in human use of automation: An attentional integration. *Human Factors, 52(3),* 381-410.

Parasuraman, R., & Miller, C. (2004). Trust and etiquette in high criticality automated systems. *Communications of the Association for Computing Machinery, 47,* 51-55.

Parasuraman, R., & Riley, V. (1997). Humans and automation: Use, misuse, disuse, abuse. *Human Factors, 39(2),* 230-253.

Parasuraman, R., & Wickens, C. D. (2008). Humans: Still vital after all these years of automation. *Human Factors, 50(3),* 511-520.

Paris, C. (2010). *Analysis of the future need and demand for appropriate models of accommodation and associated services for older people. The future housing and support needs of older people in Northern Ireland.* Online. Retrieved 2013/07/01, from http://www.nihe.gov.uk/analysis_of_the_future_need_and_demand_for_appropriate_models_of_accommodation_and_associated_services_for_older_people__published_february_2011_.pdf

Paulus, W., Hilbert, J., & Potratz, W. (2009). ICT for housing. In N. Malanowski, & M. Cabrera, (Eds.), *Information and Communication Technologies for Active Ageing: Opportunities and Challenges for the European Union* (pp. 205-215). Amsterdam: IOS Press.

Pavlou, P. (2001). Integrating trust in electronic commerce with the technology acceptance model: Model development and validation. *Americas Conference on Information Systems, 159,* 816-822.

Pavlou, P. A. (2003). Consumer acceptance of electronic commerce: Integrating trust and risk with the technology acceptance model. *International Journal of Electronic Commerce, 7(3),* 69-103.

Philips, B., & Zhao, H. (1993). Predictors of assistive technology abandonment. *Assistive Technology, 5,* 36-45.

Pohlmeyer, A. E. (2011). *Identifying attribute importance in early product development: Exemplified by interactive technologies and age.* PhD thesis, Technische Universität Berlin, Germany.

Prensky, M. (2001). Digital natives, digital immigrants, part II: Do they really think differently? *On the Horizon, 9(6),* 1-6.

Pütz, C. (2009). *Wirkungen von electronic-Word-of-Mouth-Empfehlungen bei misstrauischen Rezipienten: Eine empirische Untersuchung unter Betrachtung der Empfehlungskongruenz sowie der Botschaftsargumentation.* PhD thesis, Rheinisch-Westfälische Technische Hochschule Aachen, Germany.

Rajaonah, B., Anceaux, F., & Vienne, F. (2006). Trust and the use of adaptive cruise control: A study of a cut-in situation. *Cognition, Technology and Work, 8(2),* 146-155.

Rempel, J. K., Holmes, J. G., & Zanna, M. P. (1985). Trust in close relationships. *Journal of Personality and Social Psychology, 49(1),* 95-112.

Reuters, T. (2011). *Web of Science*. Online. Retrieved 2011/06/27, from http://thomsonreuters.com/thomson-reuters-web-of-science/

Rice, S. (2009). Examining single- and multiple-process theories of trust in automation. *The Journal of General Psychology, 136(3),* 303-319.

Rice, S., & Geels, K. (2010). Using system-wide trust theory to make predictions about dependence on four diagnostic aids. *The Journal of General Psychology, 137(4),* 362-375.

Rice, S., Clayton, K. D., Wells, A., & Keller, D. (1976). Manipulating trust behaviors in a combat identification task. *The Journal of the Human Factors and Ergonomics Society, 49(1),* 76-87.

Roberts, S. C., Ghazizadeh, M., & Lee, J. D. (2012). Warn me now or inform me later: Drivers' acceptance of real-time and post-drive distraction mitigation systems. *International Journal of Human-Computer Studies, 70(12),* 967-979.

Robinson, R. V., & Jackson, E. V. (2001). Is trust in others declining in America? An age–period–cohort analysis. *Social Science Research, 30(1),* 117-145.

Rotter, J. B. (1967). A new scale for the measurement of interpersonal trust. *Journal of Personality, 35,* 651-665.

Rotter, J. B. (1971). Generalized expectancies for interpersonal trust. *American Psychologist, 26(5),* 443-452.

Rovira, E., McGarry, K., & Parasuraman, R. (2007). Effects of imperfect automation on decision making in a simulated command and control task. *Human Factors, 49(1),* 76-87.

Sälzer, C. (2010). Besser wohnen mit Technik? *das AALmagazin, 2,* 12-16.

Sanchez, J., Calcaterra, G., & Tran, Q. Q. (2005). Automation in the home: The development of an appropriate system representation and its effects on reliance. In *Proceedings of the Human Factors and Ergonomics Society 49th annual meeting* (pp. 1859-1862). Santa Monica, CA.

Sanchez, J., Fisk, A. D., & Rogers, W. A. (2004). Reliability and age-related effects on trust and reliance of a decision support aid. In *Proceedings of the Human Factors and Ergonomics Society 38th Annual Meeting* (pp. 586-589). Santa Monica, CA.

Sanchez, J., Rogers, W. A., Fisk, A. D., & Rovira, E. (2014). Understanding reliance on automation: Effects of error type, error distribution, age and experience. *Theoretical Issues in Ergonomics Science, 15(2),* 134-160.

Sanders, T., Oleson, K. E., Billings, D. R., Chen, J. Y., & Hancock, P. A. (2011). A model of human-robot trust. Theoretical model development. *Proceedings of the Human Factors and Ergonomics Society Annual Meeting, 55,* 1432-1436.

Sayago, S., & Blat, J. (2010). Telling the story of older people e-mailing: An ethnographical study. *International Journal of Human-Computer Studies, 68(1-2),* 105-12.

Schaefer, K. E. (2013). *The perception and measurement of human-robot trust.* PhD thesis, University of Central Florida, Florida.

Scherpers, J., & Wetzzels, M. (2007). A meta-analysis of the technology acceptance model: Investigating subjective norm and moderation effects. *Information and Management, 44,* 90-103.

Schmid, A., Dörfler, I., & Dany, F. (2011). CrossGeneration – Einsatzmöglichkeiten von IT-Systemen als Antwort auf zukünftige Herausforderungen des Gesundheitssystems. In *4. Deutscher AAL-Kongress, Demografischer Wandel - Assistenzsysteme aus der Forschung in den Markt* 25-26 January 2011 Berlin, Germany.

Schneekloth, U., & Wahl, H.-W. (2005). *Möglichkeiten und Grenzen selbständiger Lebensführung in privaten Haushalten (MuG III). Repräsentativbefunde und Vertiefungsstudien zu häuslichen Pflegearrangements, Demenz und professionellen Versorgungsangeboten*. Online. Retrieved 2013/03/17, from http://www.bmfsfj.de/doku/Publikationen/mug/01-Redaktion/PDF-Anlagen/gesamtdokument,property=pdf,bereich=mug,sprache=de,rwb=true.pdf

Sengpiel, M., & Dittberner, D. (2008). The computer literacy scale (CLS) for older adults - development and validation. In M. Herczeg, & M. C. Kindsmüller, (Eds.), *Mensch und Computer 2008: Viel Mehr Interaktion* (pp. 7-16). Munich: Oldenbourg.

Shea, K., & Effken, J. A. (2008). Enhancing patients' trust in the virtual home healthcare nurse. *Computers, Informatics, Nursing, 26(3),* 135-141.

Sheridan, T. B. (1988). Trustworthiness of command and control systems. In *3. IFAC/IFIP/IEA/IFORS Conference on Analysis; Design and Evaluation of Man-Machine Systems* (pp. 14-16). Oulu, Finland.

Sheridan, T. B., & Parasuraman, R. (2005). Human-Automation interaction. Rev*iews of Human Factors and Ergonomics, 1,* 89-129.

Shinozawa, K., Reeves, B., Wise, K., Lim, S., Maldonado, H., & Naya, F. (2003). Robots as new media: A cross-cultural examination of social and cognitive responses to robotic and on-screen agents. In *Proceedings of the 53rd annual conference of the international communication association, information systems division* (pp. 998-1002). San Diego, CA.

Siegrist, M. (2000). The influence of trust and perceptions of risks and benefits on the acceptance of gene technology. *Risk analysis, 20(2),* 195-204.

Singh, I. L., Molloy, R., & Parasuraman, R. (1993). Automation-induced "complacency": Development of the complacency-potential rating scale. *The International Journal of Aviation Psychology, 3(2),* 111-122.

Society of Consumer Affairs Professionals in Business (1998). *Press release: Consumer acceptance of automated telephone system is mixed, can lead to hang ups, new report find.* Online. Retrieved 2013/05/26, from http://www.socap.org

Solaimani, S., Bouwman, H., & de Reuver, M., (2010). Smart Home: Aligning business models and providers processes - A case survey. In *Proceedings of the 21st Australian Conference on Information Systems Aligning Business Models and Providers Processes,* 1-3 December 2010 Brisbane.

Spain, R. D., & Bliss, J. P. (2008). The effect of sonification display pulse rate and reliability on operator trust and perceived workload during a simulated patient monitoring task. *Ergonomics, 51(9),* 1320-1337.

Spring, M. (1986). Home smart home. *Building, 30*, 1986.

Stanton, N. A., & Young, M. S. (2005). Driver behaviour with adaptive cruise control. *Ergonomics, 48,* 1294-1313.

Statistische Ämter des Bundes und der Länder (2010). *Demografischer Wandel in Deutschland, Heft 2, Auswirkungen auf Krankenhausbehandlungen und Pflegebedürftige im Bund und in den Ländern.* Online. Retrieved 2014/03/11, from http://www.statistikportal.de/statistik-portal/demografischer_wandel_heft2.pdf

Statistisches Bundesamt (2009). *Bevölkerung Deutschlands bis 2060 - 12. Koordinierte Bevölkerungsvorausberechnung.* Online. Retrieved 2013/07/01, from https://www.destatis.de/DE/Publikationen/Thematisch/Bevoelkerung/VorausberechnungBevoelkerung/BevoelkerungDeutschland2060Presse5124204099004.pdf?__blob=publicationFile

Statistisches Bundesamt (2011). *Im Blickpunkt: Ältere Menschen in Deutschland der EU.* Online. Retrieved 2014/04/14, from https://www.destatis.de/DE/Publikationen/Thematisch/Bevoelkerung/Bevoelkerungsstand/BlickpunktAeltereMenschen1021221119004.pdf?__blob=publicationFile

Statistisches Bundesamt (2012a). *Alter im Wandel. Ältere Menschen in Deutschland und der EU.* Online. Retrieved 2014/04/14, from https://www.destatis.de/DE/Publikationen/Thematisch/Bevoelkerung/Bevoelkerungsstand/AlterimWandel0010017129004.pdf?__blob=publicationFile

Statistisches Bundesamt (2012b). *Alleinlebende in Deutschland – Ergebnisse des Mikrozensus 2011.* Online. Retrieved 2014/04/14, from https://www.destatis.de/DE/PresseService/Presse/Pressekonferenzen/2012/Alleinlebende/begleitmaterial_PDF.html

Steinke, F., Fritsch, T., & Silbermann, L. (2012a). Trust in Ambient Assisted Living (AAL): A systematic review of trust in automation and assistance systems. *International Journal on Advances in Life Sciences, 4,* 77-88.

Steinke, F., Fritsch, T., Brem, D., & Simonsen, S. (2012b). Requirement of AAL systems – Older persons' trust in sensors and characteristics of AAL technologies. *Proceedings of the 5th International Conference on Pervasive Technologies Related to Assistive Environments, 15,* 1-6.

Steinke, F., Fritsch, T., Hertzer, A., Tautz, H., & Zickwolf, S. (2013). Expected reliability of everyday and Ambient Assisted Living technologies: Results from an online survey. *International Journal of Advanced Computer Science and Applications, 4(6),* 17-22.

Steinke, F., Bading, N., Fritsch, T., & Simonsen, S. (2014). Factors influencing trust in Ambient Assisted Living technology: A scenario-based analysis. *Gerontechnology, 12,* 81-100.

Steinke, F., Hertzer, A., & Fritsch, T. (2014). Experimental manipulation of reliability in ambient assisted living – an analysis of trust and intention to use. *International Journal of Human Factors and Ergonomics, 3(2),* 122-147.

Steinke, F., Ingenhoff, A., & Fritsch, T. (2014). Personal remote assistance in Ambient Assisted Living experimental research of elderly people trust and intention to use. *International Journal of Human Computer Interaction, 30(7),* 560-574.

Stiftung Warentest (2002). *Rauchmelder: Rechtzeitig aufwachen*. Online. Retrieved 2013/06/06, from http://www.test.de/Rauchmelder-Rechtzeitig-aufwachen-1063379-1063408/

Struve, D., & Wandke, H. (2009). Video modelling for training older adults to use new technologies. *ACM Transactions on Accessible Computing, 2(1),* 1-24.

Stuart-Hamilton, I. (1994). *The psychology of ageing: An introduction*. London: Jessica Kingsley Publishers.

Suzman, R. M., Willis, D. P., & Manton, K. G. (1992). *The oldest old*. New York: Oxford University Press.

Szalma, J. L., & Taylor, G. S. (2011). Individual differences in response to automation: The five factor model of personality. *Journal of Experimental Psychology Applied, 17,* 71-96.

Tenney, Y. J., Rogers, W. H., & Pew, R. W. (1998). Pilot opinions on cockpit automation issues. *International Journal of Aviation Psychology, 8,* 103-120.

Timmons, S., Harrison-Paul, R., & Crosbie, B. (2008). How do lay people come to trust the automatic external defibrillator? *Health, Risk and Society, 10(3),* 207-220.

Tns emnid (2011). *Wohnwünsche im Alter*. Online. Retrieved 2014/07/14, from http://www.bfw-bund.de/uploads/media/Emnid_Wohnw%C3%BCnsche_im_Alter_-_Pressemappe.pdf

Turing, A. M. (1950). Computing machinery and intelligence. *Mind, 49,* 433-460.

Turner, M., Kitchenham, B., Brereton, P., Charters, S., & Budgen, D. (2010). Does the technology acceptance model predict actual use? A systematic literature review. *Information and Software Technology, 52(5),* 463–479.

United Nations (2010). *World Population Ageing* (*2009*). New York: Department of Economic and Social Affairs.

United Nations (2013). *World Population Policies* (*2011).* New York: Department of Economic and Social Affairs.

University Duisburg-Essen. *FoSIBLE Project*. Online. Retrieved 2014/04/14, from http://fosible.eu/

Van den Broek, G. (2010). The need for interoperability and standards in AAL. In *Proceedings of the AAL FORUM 09 Vienna - Innovative ICT Solutions for Older Persons – A New Understanding* (pp. 150-155), 29 September – 1 October Vienna, Austria.

Van den Broek, G., Cavallo, F., & Wehmann, C. (2010). *AALIANCE Ambient Assisted Living Roadmap (Ambient Intelligence and Smart Environments).* Amsterdam: IOS Press.

Verband der Elektrotechnik Elektronik Informationstechnik VDE e.V. (2009). *Breite Nutzung von Ambient Assisted Living bis 2015 erwartet.* Online. Retrieved 2014/07/23, from http://www.presseportal.de/pm/9158/1342213/breite-nutzung-von-ambient assisted-living-bis-2015-erwartet

Verband der Elektrotechnik Elektronik Informationstechnik VDE e.V. (2010). *Ambient Assisted Living Roadmap*. Online. Retrieved 2014/04/14, from https://www.dke.de/de/std/aal/documents/deutsche_normungs-roadmap_aal.pdf

Venkatesh, V., & Bala, H. (2008). Technology acceptance model 3 and a research agenda on interventions. *Decision Sciences, 39(2),* 273-315.

Venkatesh, V., & Davis, F. D. (2000). A theoretical extension of the technology acceptance model: Four longitudinal field studies. *Management Science, 46(2),* 186-204.

Venkatesh, V., Morris, M. G., Davis, G. D., Davis, F. B. (2003). User acceptance of information technology: Toward a unified view. *MIS Quarterly, 27(3),* 425-478.

Vogel, M., & Zendler, A. (2009). Lateinische Quadrate und parameterfreie Auswertungsverfahren für die experimentelle Unterrichtsforschung. *Notes on Educational Informatics–Section A: Concepts and Techniques, 5(1),* 1-12.

Wälivaara, B.-M., Andersson, S., & Axelsson, K. (2009). Views on technology among people in need of health care at home. *International Journal of Circumpolar Health, 68(2),* 158-169.

Wandke, H. (2005). Assistance in human-machine interaction: A conceptual framework and a proposal for a taxonomy. *Theoretical Issues in Ergonomics Science, 6,* 129-155.

Wang, L., Jamieson, G. A., & Hollands, J. G. (2009). Trust and reliance on an automated combat identification system. *Human Factors, 51(3),* 281-291.

Warkentin, M., Gefen, D., Pavlou, P. A., & Rose, G. M. (2002). Encouraging citizen adoption of e-government by building trust. *Electronic markets, 12(3),* 157-162.

Weyrich, C. (1999). *Information society technologies advisory group: Orientations for workprogramme 2000 and beyond.* Online. Retrieved 2013/10/22, from ftp://ftp.cordis.europa.eu/pub/ist/docs/istag-99-final.pdf

Wichert, R. (2010). Challenges and limitations of intelligent ambient assisted living environments. In B. de Ruyter et al. (Eds.), *First International Joint Conference* (pp. 304-309)*,* 10-12 November 2010 Malaga, Spain. Heidelberg: Springer.

Wickens, C. D., & Colcombe, A. (2007). Dual-task performance consequences of imperfect alerting associated with a cockpit display of traffic information. *Human Factors, 49(5),* 839-850.

Wickens, C. D., & Dixon, S. R. (2005). *Is there a magic number 7 (to the minus 1)? The benefits of imperfect diagnostic automation: A synthesis of the literature.* Illinois: Aviation Research Lab.

Wickens, C. D., Rice, S., Keller, D., Hutchins, S., Hughes, J., & Clayton, K. (2009). False alerts in air traffic control conflict alerting system: Is there a "cry wolf" effect? *Human Factors, 51(4),* 446-462.

Wiegmann, D. A., Rich, A., & Zhang, H. (2001). Automated diagnostic aids: The effects of aid reliability on users' trust and reliance. *Theoretical Issues in Ergonomics Science, 2(4),* 352-367.

Wilkowska, W., & Ziefle, M. (2012). Privacy and data security in E-health: Requirements from the user's perspective. *Health Informatics Journal, 18(3),* 191-201.

World Health Organization (1984). *Uses of epidemiology in aging. World Health Organization Technical Report Series, 706, 1-84.*

World Health Organization (2011). *Health statistics and health information systems: Definition of an older or elderly person.* Online. Retrieved 2012/11/12, from http://www.who.int/healthinfo/survey/ageingdefnolder/en/index.html

World Health Organization (2013). *Ageing and life course; What is "active ageing"?* Online. Retrieved 2013/06/06, from http://www.who.int/ageing/active_ageing/en/

Xin, L., Hess, T. J, & Valacich, J. S. (2008). Why do we trust new technology? A study of initial trust formation with organizational information systems. *Journal of Strategic Information Systems*, *17(1),* 39-71.

Yeh, M., & Wickens, C. (2011). Display signaling in augmented reality: Effects of cue reliability and image realism on attention allocation and trust calibration. *Human Factors, 43(3),* 355-365.

Yousafzai, S. Y., Foxall, G. R., & Pallister, J. G. (2007). Technology acceptance: A meta-analysis of the TAM: Part 2. *Journal of Modelling in Management, 2(3),* 281-304.

Zhang, Y., & Ansarai, N. (2010). *Wireless telemedicine services over integrated IEEE 802.11/WLAN and IEEE 802.16/WiMAX Networks*. Online. Retrieved 2013/05/26, from http://web.njit.edu/~ansari/papers/10WC.pdf

Ziefle, M., & Schaar, A. K. (2011). Gender differences in acceptance and attitudes towards an invasive medical stent. *Electronic Journal of Health Informatics, 6(2),* e13.

Ziefle, M., Himmel, S., & Wilkowska, W. (2011). When your living space knows what you do. Acceptance of medical home monitoring by different technologies. In A. Holzinger, & K.-M. Simonic, (Eds.), *Information quality in e-Health. 7th Conference of the Workgroup Human-Computer Interaction and Usability Engineering of the Austrian Computer Society,* Graz, Austria (pp. 607-624). Heidelberg: Springer.

Ziefle, M., Klack, L., Wilkowska, W., & Holzinger, A. (2013). Acceptance of telemedical treatments: A medical professional point of view. In *Human Interface and the Management of Information. Information and Interaction for Health, Safety, Mobility and Complex Environments* (pp. 325-334). Heidelberg: Springer.

RESEARCH ARTICLES

The following reading order is recommended:

1. Steinke, F., Fritsch, T., & Silbermann, L. (2012). Trust in Ambient Assisted Living (AAL): A systematic review of trust in automation and assistance systems. *International Journal on Advances in Life Sciences, 4,* 77-88.

2. Steinke, F., Bading, N., Fritsch, T., & Simonsen, S. (2014). Factors influencing trust in Ambient Assisted Living technology: A scenario-based analysis. *Gerontechnology, 12,* 81-100.

3. Steinke, F., Ingenhoff, A., & Fritsch, T. (2014). Personal remote assistance in Ambient Assisted Living experimental research of elderly people trust and intention to use. *International Journal of Human Computer Interaction, 30(7),* 560-574.

4. Steinke, F., Hertzer, A., & Fritsch, T. (2014). Experimental manipulation of reliability in ambient assisted living – an analysis of trust and intention to use. *International Journal of Human Factors and Ergonomics, 3(2)*, 122-147.

RESEARCH ARTICLE 1

Steinke, F., Fritsch, T., & Silbermann, L. (2012). Trust in Ambient Assisted Living (AAL): A systematic review of trust in automation and assistance systems. *International Journal on Advances in Life Sciences, 4,* 77-88.

Trust in Ambient Assisted Living (AAL) - A Systematic Review of Trust in Automation and Assistance Systems

Frederick Steinke
Humboldt University of Berlin
Berlin, Germany
steinkef@student.hu-berlin.de

Tobias Fritsch
Heidelberg University
Heidelberg, Germany
T.Fritsch@gmx.net

Lina Silbermann
Nürtingen-Geislingen University
Geislingen, Germany
lina.silbermann@web.de

***Abstract*—The aim of the study was the investigation of the existing literature dealing with trust in Ambient Assisted Living (AAL). Additionally, a definition of trust in AAL was derived. For that purpose, a numeric analysis of articles considering the factor trust in automation, as well as assistive technologies for older people was carried out. A systematic literature review with a total of 150 dissimilar keyword-combinations, based on three different descriptors in three bibliographic online databases, was performed. This review revealed that 18 articles deal with trust in healthcare or assistance systems, but several of them only superficially. Despite the increasing market relevance in the last decade, none of the identified studies focused explicitly on trust in AAL. As can be seen from the results, older people as a target group for qualitative and quantitative research in this field are detected, but only partially examined. For obtaining access to older persons' trust in automation in general and AAL in particular, further research is needed. To identify influencing factors on trust in AAL, a broader survey and experiments with persons over the age of 60 years should be conducted.**

Keywords-AAL; Ambient Assisted Living; Assistance Systems; Elderly People; Trust

I. INTRODUCTION

As a result of demographic change, the number of people in advanced age, who want to spend a self-determined, independent life at home, is growing. Unfortunately, not all elderly people are able to reach this goal without assistance. This often leads to conflicting goals. An age-related decline in physical fitness, as well as physical limitations in consequence of diseases or accidents, mean that the elderly need support in realizing their desire to live in their familiar surroundings. This results in tension between the affordability of traditional personal care and specific individual support, as well as novel technical support. As seen in [1] the concept of trust in Ambient Assisted Living (hereinafter AAL) should be ascribed greater importance.

On one hand, human assistance in activities of daily living (ADL) like taking a bath, preparing meal or going for a walk is a great relief for people with health restrictions. On the other hand, science has, for several decades, dealt with research into new technologies to support people in their own home [2]. Meanwhile, innovations in the home environment offer numerous opportunities for technology-supported systems. Researchers have developed a plurality of services combined with technical support for elderly people. Terms as 'Smart House' [3], 'Smart Home' [4], 'Assistive Technology (AT)' [5] or 'Ambient Assisted Living (AAL)' [6] are just a few of the frequently used terms in this context.

In the present article the importance of trust in AAL for elderly people is the focal point of interest. In order to take advantage of AAL technology, which assists an impaired person in everyday life [7], the user must have trust in this assistance system. Since, in case of an emergency, this assistance can save lives, it is obvious that the concept of trust has fundamental importance to the consideration of development, purchase and use of AAL. The fact that older people have typically grown up without technologies like personal computers, smart phones or the Internet, which are often integrated in AAL [8], implies special demands towards the design of these devices.

The present study is structured as follows: Firstly, the background section explains the development of AAL as a result of demographic change. Next, the importance of trust as an influencing factor in this research context will be highlighted and a definition for trust in AAL derived. In the third section the literature review as research framework is described in detail. The acquired data is then analyzed in its entirety and moreover, studies regarding trust in healthcare and assistance systems are considered separately. Finally, a discussion of the observed results and an overview about further research activities is provided. The design of the present study is oriented to answer the research question: *Why is the investigation of trust in AAL necessary, and what is the current state of research into it?*

II. BACKGROUND

This section contains the background information about the development of AAL as a reaction to demographic change, as well as the importance of the concept of trust as an influencing factor for AAL. In conclusion, the development of a definition of trust in AAL is detailed.

A. *Development of AAL as Reaction to the Demographic Change*

According to the United Nations Department of Economic and Social Affairs (UNDESA), as compared to the total population, the proportion of people over the age of 60 years is constantly increasing [9]. The number of people over the age of 60 is predicted to grow from more than 700 million in 2009, to 2 billion in the year 2050. Worldwide this would correspond to a tripling of the cohort in a period of 40 years. The annual growth rate of 'generation 60plus' amounts 2.6 percent. This increase eclipses the overall population's growth rate of 1.2 percent per annum. At the present time, over a fifth of the population in the more developed regions is 60 years of age or over. Projections indicate that nearly one third of the total population will belong to that age group by 2050 [9]. Based on this development, health care expenditure, for example within the European Union and Norway, will change dramatically [10].

Additionally, it should be mentioned that age is not readily defined in reference only to the date of birth. Although the chronological age of two persons could be equal, the biological, psychological or social age may differ [11]. Also the cohort effect may influence differences in persons' age [12]. As defined by the World Health Organization "there is no United Nations standard numerical criterion, but the UN agreed cut-off is 60+ years to refer to the older population [11]." The terminology 'older person' or 'elderly person' is used interchangeably; therefore, these terms are similarly used in the current study for people over the age of 60. The above presented facts, in combination with the existing older persons' purchasing power, accentuate the enormous importance of the elderly for science and economy.

Moreover, technological progress and a high degree of information technology are factors that are gaining more and more relevance in everyday life. The beginning of research into the field of Assistive Technology (AT) can be traced back to the early 1970's. Then, so called "phone-chains" used the standard telephone system and were organized by a network of elderly-persons and professionals [2]. Mutual telephone calls were used to monitor the group, and if a member did not respond, their doctor or relatives were notified. This can be regarded as the first electronic emergency system for elderly persons.

The next step was the development of home emergency call systems. One of the most famous was the HTS831, which had two different buttons: one red, and one green. This system consisted of a wireless transmitter, which the user was able to wear around their neck. In case of emergency the user could either push the button on the transmitter or the red button at the station, to contact the emergency center. As a security and monitoring function, the user had to press the green button once a day [2]. In the middle of the 1990's, the first video conference system for private homes was offered. TV-top boxes, or a separate video telephone, functioned as the user interface. Additionally, this system contained functions for personal discussions and organization of, for example, nursing, medical or entertainment services [13]. In summary, efforts to develop useful and coherent life assistance services, which aid older persons to live longer in their home, have existed for several decades.

In the last few years, due to awareness of the growing distribution of older people, and technological progress, the development of AAL has significantly increased in its importance. Many national and international Non-Governmental Organizations (NGOs) and research projects have been focusing on this topic. As a result, different concepts have entered the market [8][14][15][16]. For instance, through the use of sensory floor mats - which register movements in living areas and react by automatically turning the lights on - the risk of falling can be reduced [17]. Another example of AAL can be found in the combination of personal and technological support offered by the Fraunhofer Institute [8]. By means of summarizing and demand-oriented analysis of sensor data, an individualization of care, as well as nursing services is possible. From a technological perspective it must be noted that most of the described systems are still in their early phase of innovation. Only a few AAL systems are currently marketable [18]. The German Federal Ministry of Education and Research (BMBF) launched the funding program "age-appropriate assistance systems for a healthy and independent life – AAL", which sponsored 18 research projects in the field of AAL with a total amount of € 45 million [19].

Giesecke et al. (2005) have first defined AAL "as the use of AmI [Ambient Intelligence] in everyday life. Assisted means assistance, by technical devices as well as by technical or human services [6]." In 2007, a more elaborate definition of AAL is found in [7]. Hereafter, AAL denotes "living in a smart technology supported environment that reacts sensitively and adaptively to the presence of people and objects and thus provides various services to the human. The aim is to preserve, enlarge and extend the personal freedom and autonomy, by promoting and supporting personal independence [7; translated by the authors]." Although AAL does not explicitly target the elderly and can be implemented in a huge variety of living situations for people with impairments, in practice most of the projects, which carry out research are concerned with the elderly [20]. The definition by Kung and Bart (2010) focuses particularly on enabling older people to experience of a higher quality of life. AAL refers to "intelligent systems that will assist elderly individuals for a better, healthier and safer life in the preferred living environment and covers concepts, products and services that interlink and improve new technologies and the social environment [21]."

AAL cannot be seen as a single technology but as a network of interacting systems or agents, for instance companies from different areas of society. The aim of AAL

is to combine those various agents in one holistic system adapted to diverse customer needs. As seen in [18] four different scopes for application for AAL systems called "health and care", "household and supply", "security and privacy" and "communication and social environment" exist. Due to this diversity, AAL systems should integrate in a modular design and be flexible for the customer's individual needs; lifestyle and health condition [22].

In terms of the German Association for Electrical, Electronic & Information Technologies, AAL is defined as follows: "Assistant systems for the constitution of intelligent environments [aiming] to compensate predominantly age-related functional limitations of different target groups – through technological information and communication support in everyday life [23]." This definition emphasizes the role of information and communication technology in particular.

In contrast to home automation [24] or the smart house [3], AAL is not limited to only life in relation to housing, but extends to all areas of life. AAL focuses on the assistance functions of an adaptive overall system while home automation deals mainly with automation and networking of devices. AAL focuses on maintaining, increasing and extending the user's personal freedom and autonomy. In summary, AAL systems are intended for people with health impairments who require security in their environments and support in communication to prevent loneliness. The present European research focuses on these overall requirements of elderly persons. Since the concept of AAL is concerned with these holistic requirements, the importance of trust in AAL needs to be more understood for permanent usage.

B. The Concept Trust as Influencing Factor for the Usage of AAL

"There are multiple definitions of trust and a single, simple definition is insufficient to capture the essence of the concept [25]." This definition shows the plurality of the concept of trust. As seen in [26] the conception of trust arises in many disciplines like social psychology, philosophy, economics, law, marketing and others. These diverse disciplines also have different basic requirements about trust. The economists have a rational and calculative vision of trust, which contrasts with the attitudinal and ethical view of the philosophers. Social psychology emphasizes the reliability of the word and the fulfillment of obligations [27]. On the other hand, economics perceives trust as an answer to expected future behavior and suggests the usage of hostages to warrant rational behavior [28]. Furthermore, philosophy and social psychology emphasize the personal and interpersonal aspects, while law economics and marketing stress inter organizational trust. The fact that trust depends on additional situational and cultural elements, together with existence of diverse synonyms, highlights the multidimensional view of the concept and demonstrates why there is no uniform definition of the term [26].

Castaldo et al. (2010) used a quantitative approach to illustrate and handle the heterogeneity of trust by means of a content analysis. By application of 36 definitions of the term "trust", a frequency analysis was conducted. The numbers in co-occurrences show that attitude and behavior were used in most of the cases to explain trust [29].

To emphasize the diversity of the construct trust there are added numerous 'trust relationships'. Personal trust, as self-confidence, and interpersonal trust that comprises a human's trust with another human [27][30][31] can be mentioned. [32] put their research focus on close relationships and stated that trust is not present from the beginning. It has to be built up through increasing experience with the other person. Moreover, social trust characterizes trust with a system or an institution [26], while trust in automation denotes a human's trust with a technology or a device [33][34][35].

"Uncertainty, vulnerability and the possibility of avoiding risk or of making a choice based on judgment, are seen as necessary conditions for the existence of trust" [26]. The enhanced uncertainty and complexity that has stimulated the latest interest in trust in various fields of research corresponds with the increased relevance of healthcare and trust in assistance systems and automation in general. Trust in technology induces reliance when the complexness makes a thorough understanding impossible.

Turing (1950) was the first who analyzed trust between humans and machines in an experiment where a human had to differentiate between a human advisor and a computer simulating a human. 95 percent of the participants did not notice the difference and supposed that the advisor was a human. With the 'Turing Effect' the discussion about human trust in information given by automation compared to another human, was born [36].

New and innovative technologies become increasingly complicated and humans cannot manage the full degree of complexity. Humans cannot fully understand the processes behind the automation. They have to rely on automation to use it in an adequate manner. Therefore, trust can be seen as a mediator between humans and automation by guiding reliance: "Trust can be defined as the attitude that an agent will help achieve an individual's goals in a situation characterized by uncertainty and vulnerability" [37]. The agent is described as automation or as a person, which cooperates with the surrounding of the person [37].

As seen in different studies, people have the tendency to rely on technology they have trust in and to reject technology they do not trust [33]. When people trust automation, the usage is often influenced positively [38][39]. But also negative examples exist due to inappropriate calibration of user trust. In one notable example, the cruise ship Royal Majesty ran aground because the crew did not realize that the navigation system did not work correctly. The system lost the GPS signal and the alarm did not inform the crew. Although it was obvious to see that the water became too shallow, the disaster was not averted. A subsequent report confirmed that the crew was overly reliant on the automated position display [40]. Another tragic example of distrust towards automation led to an airplane crash where 71 people lost their lives [41]. The collision near Überlingen at Bodensee in 2002 can be attributed to the ignorance towards the Traffic Collision and Alerting System (TCAS). Two airplanes were flying in the same height and the TCAS warned both about the imminent accident. It advised the

Tupolew to ascend and the Boeing to descend but a human air traffic controller was not aware of the other airplane's position. He gave the conflicting advice to the Tupolew to descend. The Tupolew pilots' followed the human's advice and thus the collision was caused. This case represents a typical dilemma of human advisory conflicting with automation advisory. These examples show the importance and impacts of trust towards technology. If trust is not calibrated to the true capacity of the system, users may over rely (misuse) or under rely/ reject (disuse) on the automation [42].

These considerations relating to trust in technology can also have impact in the area of healthcare and AAL. As seen in [43], trust in medical technology is empirically different from trust in other technology. Based on [35], which deal with patients and healthcare providers in obstetric work systems, important implications for trust in healthcare systems and AAL-Technology emerge. The study demonstrates that trust building in medical technology transpires not only in a relationship between doctor and patient or patient and technology. There is a complex network of relationships, which ultimately forms a 'network of trust' in technology use. [44] has already observed a network of trust in supervisory control systems. In addition to the sys-tem she included a system designer, operators, management and society as other actors. Trust as a factor attributed to AAL systems, is also affected by a significant amount of implicit trust in the network around the use of the actual technology. Following the 'Actor Network Theory' [45][46], the reliance on the network located around the AAL system, is equally important for the usage of assistive technology. As an example, for [47] the use of a defibrillator implies not only trust in the product and its functions but also in the network around this product. This network includes the product designer, the organization, which implements the product and the coaches, explaining the technology to the inexperienced users [47]. It follows that distrust in a health care provider can also lead to patients' distrust in medical technology or the hospital per se [48]. Therefore, consideration of the social or work system [49], which encapsulates the technology, is necessary for an understanding of trust. Reference [35] clarified that in the case of complex medical or assistance technology, building trust in automation is more accurately building trust in a work system. Furthermore, during the use of the same system the perspectives of multiple user groups (end user, relatives, and health care provider) vary [35].

In summary, it can be seen that there are a lot of factors, which differ in the formation of trust and, which have to be considered in the development and application of AAL. Due to the importance of the concept of trust it is necessary to develop a working definition as a basis for further research activities in AAL. The following definition based on the above mentioned definitions of AAL [6][21][23] and the definition by [37] in context with automation.

Trust in Ambient Assisted Living (AAL) can be de-fined as the attitude that an assistive technology supports an impaired person within their social environment in an uncertain and vulnerable situation.

AAL also offers holistic support for persons with disabilities, not only to those over the age of 60 years. The combination of human and technical services by modular and customized technology generates various possibilities. Since users will not completely understand the technology and processes of AAL, the attitude trust helps to influence the usage of AAL.

III. RESEARCH FRAMEWORK

A literature review was conducted to explore the relevant scientific approaches in the context of trust in AAL, healthcare assistance systems and other automation. By means of this research method, information about how extensively the issue has been previously addressed in the research can be ascertained. To increase the precision of the literature review in this innovative and fast moving research field, relevant articles were identified by means of computerized search in the online bibliographic databases 'Web of Science' [50] 'PubMed' [51] and 'PsycINFO' [52] starting in November 2010 up to a publication date of January 2011. The three database searches are carried out with filter. In 'Web of Science' key search terms are filtered by topic, in 'PubMed' by MeSH Terms and in 'PsycINFO' by keywords. These three different terminologies represent the generic terms for the search algorithm in the respective database.

For investigation in the three databases, 150 dissimilar search term combinations are performed in each setting. The used key search terms are presented in Table I. The first search requests always contain a term of the categories 'Attributes' and 'Auxiliaries'. At first, the term trust has been set and was queried alternatively with the keywords of the descriptor 'Auxiliaries'. After carrying out these searches, the term reliance was set and also requested with those from the second category. Then, the already carried out 30 search combinations have been linked sequentially to the concepts of the third descriptor 'Population'. By extending the research with these four search terms and consideration of the abbreviations AAL and ATS, ultimately 150 searches per database were performed.

Due to the large number of search combinations and potentially relevant studies, the search results are already reviewed for further availability during the database search. For this, both title and abstract are considered. Afterwards, to identify the relevant full text articles a set of exclusion criteria are selected. For inclusion in the literature review articles had to fulfill the following criteria:

TABLE I. KEY SEARCH TERMS

Attributes	Auxiliaries	Population
Reliance	Ambient Assisted Living/ AAL	Adult
Trust	Assist* System/ Technology	Age*
	Assistive Technology Service/ ATS	Elder*
	Automation	Old*
	Healthcare	
	Intelligent/ Interactive Home	
	Medical Technology	
	Smart Home/ House/ Living Technology	

*Search included stated terms and derivates (e.g., age, aging, aged).

(1) The study described explicitly the connection between trust and automation or assistive technology, whereby trust is seen as an influence factor for the interaction with the system

(2) The article was published in a journal or presented at an international conference

(3) Studies, which were first presented at a conference and afterwards published with identical findings as a journal article, were only taken into consideration with the journal release

(4) The publication was written in English

(5) Due to the database research date, studies are included up until January 2011.

A data form was used to remove the important information for each relevant article. After structuring the articles and integrating the data in the fact sheet, a detailed data analysis was undertaken.

IV. DATA ANALYSIS

The previously described 150 search term combinations in each database initially identified 8,498 potentially relevant articles for the literature review. By means of the structural query, the database 'Web of Science' offered 4,401 publications. The database 'PubMed' yielded 3,855 results and the search requests in 'PsycINFO' provided 242 studies. Owing to the consideration of the above described five exclusion criteria and after analyzing titles and abstracts of the 8,498 studies, 164 publications are used in the next part of the review. In this step, the full text of these 164 articles was reviewed. After analysis of the full text versions, 92 articles were included for the further literature analysis. With regard to the exclusion criteria, a total of 72 of the filtered studies were excluded, leaving 56 percent of the original 164 articles. Fig. 1 gives a numerical overview about the structural sequence of the literature research.

Because of the five exclusion criteria shown above, 72 articles (44 percent) were excluded after the full text review.

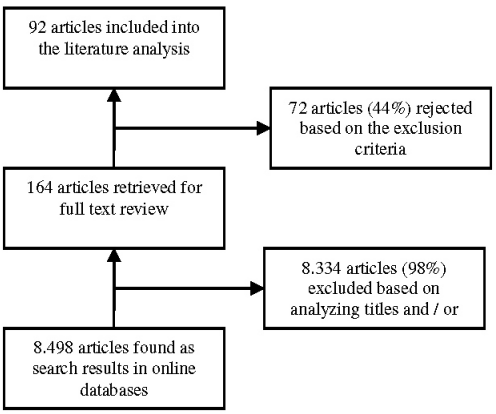


Figure 1. Literature research sequence diagram (authors design).

Most of the studies (48 articles) are not relevant due to the wrong topic focus. 15 of these studies had focused on trust in websites/ online platforms as well as trust in e-commerce applications and are not followed up owing to the exclusion criterion. A further 17 studies are eliminated since they were not published at a conference or in a journal. The last seven excluded articles were published once in a journal and additionally published at a conference with almost identical results. These studies are only considered one time with the more current journal article in our results. Thus, in the end, 92 articles were analyzed in detail in the literature review.

These articles covered the topics trust in automotive [53][54][55][56][56][57], aviation [40][58][59][60][61][62][63][64][65], combat identification [66][67][68][69][70], general design advancement [33][71][72][73][74], supervisory control systems [38][39][75][76][77][78], healthcare and assistance systems [79][80][81][82][83][84] and others [85][86].

As can be seen in Fig. 2, with a total of 18 articles the cluster 'Healthcare and Assistance Systems' has the largest number of relevant studies. This fact can be explained due to the specific key search terms in the descriptor 'Auxiliaries' (e.g., 'Healthcare', 'Assistance/Assistive System/ Technology', or 'Medical Technology') in the first step of the literature search. These articles will be analyzed with special regard in the further course of the study. Firstly, the other six clusters with focus on measuring and analyzing trust in technology will be briefly addressed.

Diverse computerized trials and experiments relating to trust in automation and assistance by means of transportation 'Aviation' (16 articles) or 'Automotive' (11 articles) were performed. In the consideration of the articles in the cluster 'Aviation', the focus is on research in air traffic control (e.g., [62][63][65] and multitask flight simulation [40][59][58]. The background of this field of research is that pilots' trust in alarms or cues within cockpit automation has impact on the usage of autopilot systems. Recent results can be found in [60][61][64].

In the cluster 'Automotive', reliance in automotive

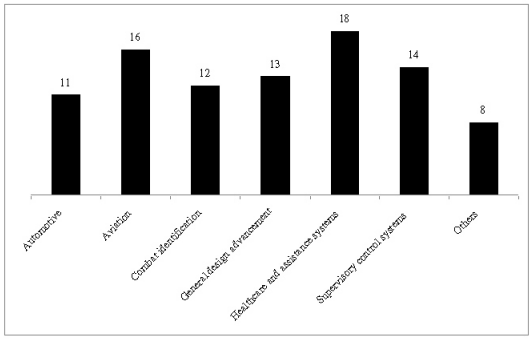


Figure 2. Numerical division of the literature review results by topic (alphabetical order) (authors design).

adaptive cruise control systems [57][87], advanced traveler information systems [55] and particular automotive collision warning systems (e.g., [53][54]) play an important role in research. These computer-assisted experiments aim to analyze trust in different alarm types as false alarm (FA) or unnecessary alarms (UA) in simulated driving situations [56].

Furthermore, in the last decade the military has integrated the factor of trust in 'Combat Identification' in its research projects [66][70]. The literature research included 12 studies on this military subject. The authors in this cluster examined the effects of trust and human responses to automation alerts and false alerts. Participants, who are performing simulated combat tasks, often have to analyze aerial photographs for the presence of enemy targets. Research developments can be seen in [67][68][69].

In addition, 13 articles, among eight former literature reviews, observe trust in 'General Design Advancement' [33][37][73][74]. Jian, Bisantz, and Drury (2000), the only quantitative study in this cluster, developed a trust questionnaire in human-machine interaction, which today is used for measuring trust in various automated systems [71].

Further 14 articles deal with reliance on different 'Supervisory Control Systems'. Monitoring of luggage screening [76], pumping [37][39][78] and central heating systems [77] have been considered in this category. Moreover, Bahner, Hueper, and Manzey (2008) have regarded a process control system and the influence of complacency and automation bias in interacting with a decision aid in this context [75]. Finally, a cluster called 'Others' was created for including all studies, which cannot be integrated in one of the before mentioned sub items. These articles concentrate for example on trust in tele-operation systems [88], automation etiquette [86] or trust in an automated counting and circle estimation task [85].

A. *Data analyses of overall results*

In the next step, the data sheet with the overall studies has been analyzed (A) and compared with the results from the topic trust in healthcare and assistance systems (B).

(1) Publication date

Between 1987 and 1991 only two studies were published in this context [33][34]. The first experiment of trust in a human-machine supervisory control system was realized by [38]. Whereas, up until 1999, 15 studies were published in total, from 2000 to 2010, 77 articles with regard to trust in technology and assistance systems can be found. Since 2003, every year six studies or more are indicated. In 2008, a maximum of 11 relevant articles are found.

(2) Type of study

In a next step, the distinction between conceptual and empirical/experimental articles is examined. From the overall 92 reviewed studies, 22 consider conceptual and 70 empirical methods for their research. These conceptual articles comprise former summaries and literature reviews (12 articles) as well as articles with the focus on framework, model or questionnaire development (10 articles). The 70 empirical articles can be differentiated into quantitative and qualitative research methods. Since 1987, in total 62 quantitative studies (including experiments, online, postal or paper standardized questionings or a combination of experiment and questioning) were identified. It can be observed, that only five studies include questionnaires only. In contrast, 57 studies used experiments or a combination of experiments and questionnaires for measuring trust. By comparison, eight articles with qualitative methods as qualitative interviews, workshops and focus group interviews were considered.

(3) Participants characteristics

In a next step, the participants' age distribution is considered. In order to receive a better understanding of the participants in experiments or surveys, a clustering into five age groups was conducted. These groups were subdivided into 'participants younger than 30 years' 'participants from 30 to 60 years', as well as 'participants older than 60 years'. Moreover, one age group comprised a combination of younger (< 30 years) as well as older (> 60 years) participants. Further studies performed experiments or interviews without age differentiation.

Regarding the 70 empirical studies, in 22 of the studies or 31 percent, there was no age differentiation declared. In 35 surveys participants were younger than 30 years and in five surveys they were between the ages of 30 and 60 years. In only eight surveys (16 percent of overall) were participants older than 60 years. In five articles the participants exclusively belonged to the age group over 60 years. In three further studies both younger participants (< 30 years) and people over the age of 60 were examined.

Participation rates range from an experiment with six [89] or a qualitative interview with nine participants [90] to a postal survey with 1187 participants [91]. In total, in 43 of the articles (61 percent) less than 50 participants took part in the surveys on trust in automation or assistance systems. In eight studies between 51 and 100 and in 16 studies between 101 and 500 participants were involved. Reference [91] was the only study with more than 500 participants. In two articles there was no participant number specified. Moreover, only three out of the surveys contained a limitation with regard to the gender. One study by [82] questioned 24 women, or rather 24 mothers who had recently given birth. In two other articles only male participants, former pilots [92] and students [93], were surveyed. In 38 surveys both gender were examined and 29 surveys did not make an explicit distinction.

(4) Publication type

Another study detail can be carried out by the differentiation between 'conference vs. journal publication'. Among the 92 examined articles, 18 articles (20 percent) were presented at a corresponding conference and 74 articles published in a journal. The journal with the most publications and major interest in the research of trust and automation was 'Human Factors' with a total of 21 articles (23 percent). The journal 'Ergonomic', with eight relevant articles, the 'International Journal of Industrial Ergonomics', with four and several journals with three studies follow.

B. *Data analysis of studies regarding trust in healthcare and assistance systems'*

This rising relevance of the concept of trust, which can be found in the different research topics, is also evident by the large number of relevant articles in trust and 'healthcare and assistance systems'. In this field of research interest has been increasing in the last decade.

(1) Publication date

The first published paper relating to trust in healthcare automation was presented in 2002. The conference paper by [86] was the first article that emphasized the factor trust. From this point on until January 2011, 18 articles can be found. These articles deal with reliance on healthcare, medical or household assistance systems. In the years 2003, 2004 and 2006 no publications within this context can be found, whereas since 2007, every year articles are considered. 2010 revealed the largest number of studies in field, with five published. Fig. 3 gives a detailed overview about the annual distribution of the studies in the cluster 'healthcare and assistance systems' in comparison to the other topics. As can be seen, the importance of a conscious handling and perception of the concept of trust in combination with automation and, particularly, healthcare and assistance systems has been increasing in recent years. The first study with regard to trust in automation and human-machine interaction was published in 1987 [33]. In contrast, the first publication regarding trust as a variable for developing healthcare systems for older persons was presented in 2002 [81].

(2) Type of study

Four of the 18 articles in this cluster used conceptual methodologies. Three articles focused on framework or model development [79][81][83] and one study summarized the relevance of training in technology used by tele-home care nurses [84]. Moreover, 14 articles included empirical research–seven used quantitative and seven qualitative methods. The publications with quantitative methodologies are divided into three studies with a combination of questionnaire and experimental design, two studies with exclusive questionnaire surveys and two with experiments. The qualitative research exclusively consists of articles with qualitative interviews.

In comparison, within the other topics quantitative studies dominate with 55 studies. In particular, in new research areas qualitative surveys are utilized to get a detailed understanding of the topic. For this purpose, the focus is set on qualitative interviews, as has occurred in the research area of trust in healthcare and assistance systems. Seven of the overall 18 studies (39 percent) included qualitative interviews with individuals or workshop and focus group discussions. In 2010, four studies used qualitative interviews, which show that researchers are still in the process of developing a detailed understanding. Given that general research on trust in human-machine interaction started in 1987 [33] and to this day ambiguities in this context exist [60][61][94] it is understandable that qualitative interviews are still used in this research area.

(3) Participants characteristics

For the 14 empirical articles an age group differentiation was performed. In three of the studies, participants were younger than 30 years and in one study they are between 30 and 60 years. Moreover, five of the articles consider participants over the age of 60 years. Further two studies consider a combination of younger and older participants, while three surveys give no information about age differentiation. Where the work system is in healthcare and assistance systems such as AAL, the end user is mostly over the age of 60. Therefore, it is of immense relevance that this target group will be considered in the research. Fig. 4 displays the previous study numbers, in which participants over 60 years were involved.

As can be seen, in the other clusters the target group of people over the age of 60 plays only a subordinate role. Only one author has considered elderly persons' trust in a human-decision aid system and compared the results to people younger than 30 years [85].

In contrast, in the healthcare sector researchers have focused more on the age group over 60 years. Of the total of

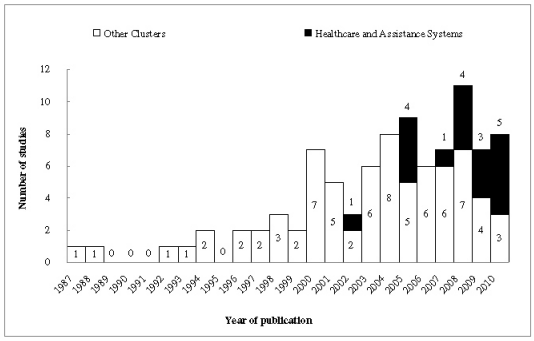


Figure 3. Year distribution of studies in 'healthcare and assistance systems' vs. other topics (authors design).

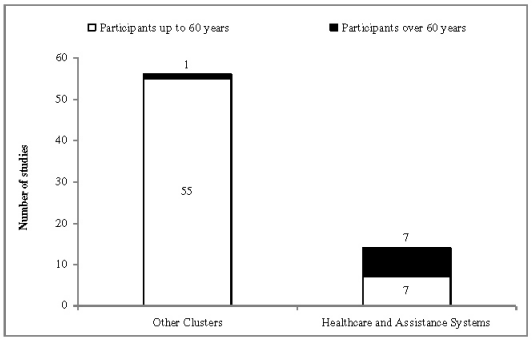


Figure 4. Age differences of study participants in the different clusters (authors design).

eight studies that have dealt with participants over 60 years, seven studies (88 percent) are located in this cluster. Two studies have taken a differentiation of younger and elderly persons into account [80][95]. Moreover, five articles have exclusively focused on people over 60 years [90][96][97][98][99]. In 50 percent of the overall studies, which analyze the factor of trust in healthcare and assistance systems by experiments or surveys, the age group over 60 years is strongly represented.

Concerning the number of participants in the topic 'healthcare and assistance systems', in nine of the studies the participant rate amounted to less than 50 participants. In two studies the participant rate ranged from 51 to 100 persons and three articles took more than 100 participants into account. These articles also include the reference [91] with a postal questionnaire of 1187 people. With reference to the participant rate it can be highlighted that the study with the most participants [91] as well as one of the studies with the least participants (n=9) [90] belong to the topic trust in healthcare and assistance systems.

Regarding the gender distinction within the different methodological designs, 12 articles have regarded both sexes; one article made no differentiation and one study [82] viewed only female participants. This study with solely female participants interviewed 24 women who had recently given birth. They were questioned in a qualitative interview to analyze trust in medical technology and obstetrics work system [82]. For the observation of this complex work system additional interviews with care providers were conducted [35]. Furthermore, it can be said that healthcare and technical support for elderly persons are themes, which concern men and women equally. Therefore, it seems logical that most of the studies deal with both genders.

(4) Publication type

Moreover, among the 18 studies, six articles (33 percent) are presented as conference papers and 12 articles (67 percent) were published in journals. The journal 'Ergonomics' with two publications was the only one, which was represented several times. The author Enid Montague with four research studies since 2009 has taken a pioneering role in context of trust and healthcare technology [35][43][82][83]. Additionally, Coughlin et al. (2007, 2009) and Ho et al. (2005a, 2005b) are listed with two articles [79][80][96][100].

Due to the topical nature of the research field, the distribution of articles presented at conferences and published in journals can be explained. From the overall 18 studies in the healthcare cluster, 12 were published in journals and six studies were presented at conferences. By comparison, from 74 articles within the other topics, 62 were published in journals and 12 studies, thus 16 percent, were presented at conferences.

V. CONCLUSION AND FUTURE WORK

The significant increase of elderly persons due to demographic change and the resulting rise in purchasing power is affecting the development of reliable AAL systems [101]. Since 2005 the European and national sponsoring programs for AAL have steadily increased the relevance of supported living in a home environment, which enlarges and promotes personal independence. Moreover, it is difficult to understand why AAL has had absolutely no consideration in combination with measuring trust in the research literature. The search combinations 'reliance or trust' and 'Ambient Assisted Living/ AAL' yielded no results in the current literature study. There was no study explicitly examining trust in AAL systems. Moreover, the relevance of measuring trust in healthcare technology and assistance systems is not prominent within the research results. It can be seen that the consideration of trust in connection with healthcare, medical technology or assistance systems is still in a nascent stage. A few studies considered trust in intelligent home systems [100], smart home [96], telemedicine systems [98], as well as automation [95] or technology [90] at home. Furthermore, it must be noted, that there is no consistent terminology for assistance systems for elderly persons. No systematic approach and documentation or a uniform technology and understanding exist in research, which complicated measuring trust in this context.

On one hand, these results could imply that the topic has not been viewed as a relevant scholarly topic. On the other hand, due to the increasing number of studies in the last decade, this suggestion seems not to be supported. Analyzing the publication date shows that all relevant articles were composed in this period. It is evident that the research field has gained in importance in the last decade.

Another interesting fact can be found in the different frequency distribution of quantitative and qualitative studies. In the analysis of the type of study it can be highlighted that researchers who are examining trust in healthcare and assistance systems use qualitative as well as quantitative methodologies. The fact that trust in healthcare and assistance systems do not singularly depend on technology but rather on a complex work system [35][47], underlines the relevance of more substantial research into this topic.

Moreover, researchers have recognized that the characteristics of elderly participants have been taken into account. An analysis of trust in this sector can only be realized by the integration of people over the age of 60. Seven articles in the last decade consider older participants' trust in healthcare and home assistance systems. The increasing demand and importance of AAL due to the higher life expectancy and demographic shift clarify a considerable backlog demand in measuring elderly persons' trust in AAL. More research into this age group is required to fill the gap left by the few studies and quantitative results. Finally, it can be surmised that by reason of the novelty of the research of measuring trust as an influencing factor for using healthcare and assistance systems, the exact influence of trust cannot be quantified. Only 18 articles, which cover that topic, were found owing to the literature review. Initial developments reveal that trust in healthcare and medical technology differs from reliance on other technologies [43].

Both, qualitative and quantitative research is required to cope with increasing demands in the coming years. Furthermore, more elderly participants must be taken into account for measuring and conceiving trust in an AAL system. In order to ascertain trust the elderly have in AAL, a

deeper understanding of their needs as well as fears and worries is essential. Additionally, trust of reference persons may have influence in using AAL. For researchers and designers of AAL, recognizing the influencing factor of trust will support the development of marketable solutions.

Due to the knowledge gained by the literature review, further research in the context of elderly persons' trust in AAL will be conducted. Based on the results of the present study, the variables regarding trust in AAL have to be examined in a next step. The investigation conforms the various influence factors on trust in AAL and beyond the connection to the usage intention. For this, a scenario-based questionnaire survey and additional experiments will be performed. The experiments include mock-ups of AAL technology on tablet PCs. Different scenarios will be conducted by older test persons. The impact of personal and technical assistance within AAL will be examined and afterwards reliability of AAL technology manipulated.

LIMITATIONS

The systematic review had to contend with some limitations in the research process. First, the selection of online databases should be considered. Literature for trust in automation and healthcare can be seen as an interdisciplinary field. Therefore, three bibliographic databases were used: 'Web of Science' comprising of interdisciplinary content across 256 disciplines; the database 'PubMed' focusing on healthcare content; and 'PsycINFO', psychological literature. Due to this selection, articles, which are not integrated in these databases, are excluded for the review. Second, the information provided in the articles is very heterogenic. Some include a specific description about the experimental design, while other studies fail to provide detailed information. Third, due to the fact that only English language articles were included in the review, a distorted picture is drawn, as the studies focus on English-speaking authors. Fourth and finally, the studies included in the literature review were screened up until January 2011. Thus, articles, which were published afterwards, are not considered for this systematic review.

REFERENCES

[1] F. Steinke, T. Fritsch, and L. Silbermann, "A Systematic Review of Trust in Automation and Assistance Systems for Older Persons' Overall Requirements," eTELEMED 2012 The Fourth International Conference on eHealth, Telemedicine, and Social Medicine, Valencia, 2012, pp. 155-163.

[2] W. Paulus, J. Hilbert, and W. Potratz, "ICT for Housing," in Information and Communication Technologies for Active Ageing. Opportunities and Challenges for the European Union, N. Malanowski and M. Cabrera, Eds. Amsterdam, 2009.

[3] G. Leopold, "Will 'Smart House' Provide Shelter for High-Tech Firms?," Electronics, vol. 58(26), 1985, pp. 45-46.

[4] M. Spring, "Home smart home," Building, vol. 30, 1986.

[5] B. Philips, and H. Zhao, "Predictors of assistive technology abandonment," Assistive Technology, vol. 5, 1993, pp. 36-45.

[6] S. Giesecke et al., "AAL - Ambient Assisted Living: Country Report Germany, White Paper, 2005.

[7] T. Becks, J. Dehm, and B. Eberhardt, "Ambient Assisted Living. Neue "intelligente" Assistenzsysteme für Prävention, Homecare und Pflege," Frankfurt am Main, 2007.

[8] Fraunhofer, „Zuhause Daheim: Das Projekt JUTTA," 2011, retrieved on 12-11-2012, retrieved from http://www.inhaus.fraunhofer.de/Geschaeftsfelder/Health-und-Care/jutta.jsp.

[9] UNDESA, "World Population Ageing 2009," Department of Economic and Social Affairs: Population Division, New York, 2010.

[10] European Union. "The 2012 Ageing Report: Underlying Assumptions and Projection Methodologies," European Economy April 2011, retrieved on 11-12-2012, retrieved from http://ec.europa.eu/economy_finance/publications/european_economy/2011/pdf/ee-2011-4_en.pdf.

[11] World Health Organization (WHO), "Health statistics and health information systems: Definition of an older or elderly person," 2011, retrieved on 11-12-2012, retrieved from http://www.who.int/healthinfo/survey/ageingdefnolder/en/index.html.

[12] I. Stuart-Hamilton, "The psychology of ageing: an introduction," 2n ed. London: Jessica Kingsley Publishers, 1994.

[13] J. Hilbert, K. Scharfenorth, and J. Haberle, "Vom Virtuellen Altenheim zu TESS inkontakt. Erfahrungen aus einem Entwicklungs- und Erprobungsprojekt für mehr Lebensqualität im Alter," IAT, Ed., Jahrbuch 1998/1999, 1999, pp. 132-143.

[14] BMBF, "Assistenzsysteme im Dienste des älteren Menschen. Steckbriefe der ausgewählten Projekte in der BMBF-Fördermaßnahme „Altersgerechte Assistenzsysteme für ein gesundes und unabhängiges Leben – AAL", 2010, retrieved on 11-12-2012, retrievd from http://www.vde.com/de/Technik/AAL/Steckbriefe/Documents/sens@home.pdf.

[15] W. Heusinger, "Das intelligente Haus- Entwicklung und Bedeutung für die Lebensqualität," Frankfurt am Main, 2005.

[16] S. Solaimani, H. Bouwman, and M. de Reuver, "Smart Home: Aligning Business Models and Providers Processes; A case survey," Proceedings of the 21st Australian Conference on Information Systems Aligning Business Models and Providers Processes, Brisbane, 2010.

[17] C. Sälzer, "Besser wohnen mit Technik?," Das AALmagazin, vol. 2, 2010, pp. 12-16, retrieved on 11-12-2012, retrieved from http://www.smartliving-gmbh.de/downloads/Besser%20Wohnen%20mit%20Technik.pdf.

[18] P. Georgieff, "Ambient Assisted Living: Marktpotenziale IT-unterstützter Pflege für ein selbstbestimmtes Altern," Stuttgart: MFG Stiftung Baden-Württemberg, 2008.

[19] Bundesministerium für Bildung und Forschung (BMBF), "Assistenzsysteme im Dienste des älteren Menschen – Steckbriefe für ausgewählte Projekte in der BMBF-Fördermaßnahme ‚Altersgerechte Assistenzsysteme für ein gesundes und unabhängiges Leben – AAL'," 2009, retrieved on 11-12-2012, retrievd from http://www.bmbf.de/pubRD/projekte_aal_2012.pdf.

[20] R. G. Heinze, and C. Ley, "Abschlussbericht des Forschnungsprojektes Vernetztes Wohnen. Ausbreitung, Akzeptanz und nachhaltige Geschäftsmodelle," T-Mobile Deutschland GmbH (Bonn). Bochum, 2009, retrieved on 11-12-2012, retrieved from http://www.sowi.rub.de/mam/content/heinze/heinze/abschlussbericht_vernetzteswohnen.pdf.

[21] A. Kung, and B. Jean-Bart, "Making AAL Platforms a Reality," Proceedings of the AMI 10 workshop (AmI-10). Ambient Intelligence. Lecture Notes in Computer Science, 2010, vol. 6439, 2010, pp. 187-196.

[22] R. Wichert, "Challenges and limitations of intelligent ambient assisted living environments," in: Ambient intelligence. (de

Ruyter, B. et al., eds.), Proceedings of the First international joint conference, AmI 2010, Málaga, Spain, November 10-12, 2010, Springer, pp. 304–309.

[23] M. Gersch, R. Lindert, and M. Hewing, "AAL-business models: Different prospects for the successful implementation of innovative services in the primary and secondary healthcare market," Proceedings of the AALIANCE European Conference on AAL, Malaga, 11-12 March 2010, retrieved on 12-11-2012, retrieved from http://www.aaliance.eu/public/oldstuff/aaliance-conference-1/papers-and-posters/8_2_fu-berlin.

[24] I. Miles, "<Shift> <Control>,...<Home>? A Response to Robins and Cornford," Futures, vol. 22(8), 1990, pp. 880-885.

[25] D. C. P. Holland, and P. A. G. Lockett, "Business trust and the formation of virtual organizations," Proceedings of the 31 Annual Hawaii International Conference on System Sciences, volume IV, 1998, pp. 602-609.

[26] K. Blomqvist, "The many faces of trust," Scandinavian Journal of Management, vol. 13(3), 1997, pp. 271-286.

[27] J. B. Rotter, "A new scale for the measurement of interpersonal trust," Journal of Personality, vol. 35, 1967, pp. 651–665.

[28] N. G. Noorderhaven, "Trust and inter-firm relations," Proceedings of the 1992 EAEPE Conference, 1992.

[29] S. Castaldo, K. Premazzi, and F. Zerbini, "The Meaning(s) of Trust. A Content Analysis on the Diverse Conceptualizations of Trust in Scholarly Research on Business Relationships," Journal of Business Ethics, vol. 96, Number 4 (2010), pp. 657-668.

[30] M. Deutch, "Trust and suspicion," Journal of Conflict Resolution, vol. 2, 1958, pp. 265–279.

[31] M. Deutch, "The effect of motivational orientation upon trust and suspicion," Human Relations, vol. 13, 1960, pp. 123-139.

[32] J. K. Rempel, J. G. Holmes, and M. P. Zanna, "Trust in close relationships," Journal of Personality and Social Psychology, vol. 49, 1985, pp. 95-112.

[33] B. M. Muir, "Trust between humans and machines, and the design of decision aids," International Journal of Man Machine Studies, vol. 27, 1987, pp. 527–539.

[34] T. B. Sheridan, "Trustworthiness of command and control systems," in 3. IFAC/IFIP/IEA/IFORS Conference on Analysis; Design and Evaluation of Man-Machine Systems, Oulu, Finland, 1988, pp. 14-16.

[35] E. N. H. Montague, W. W. Winchester III, and B. M. Kleiner, "Trust in medical technology by patients and healthcare providers in obstetric work systems," Behaviour & Information Technology, vol. 29(5), 2010, pp. 541-554.

[36] A. M. Turing, "Computing machinery and intelligence. Mind," vol. 59, 1950, pp. 433-460.

[37] J. D. Lee, and K. A. See, "Trust in automation: Designing for appropriate reliance," Human Factors, vol. 46(1), 2004, pp. 50–80.

[38] J. Lee, and N. Moray, "Trust, control strategies and allocation of function in human-machine systems," Ergonomics, vol. 35, 1992, pp. 1243–1270.

[39] J. D. Lee, and N. Moray, "Trust, self-confidence, and operators' adaptation to automation," International Journal of Human-Computer Studies, vol. 40, 1994, pp. 153–184.

[40] R. Parasuraman, and C. Miller, "Trust and etiquette in high-criticality automated systems," Communications of the Association for Computing Machinery, vol. 47(4), 2004, pp. 51–55.

[41] BFU, "Untersuchungsbericht AX001-1-2/02. Edited by Bundesstelle für Fluguntersuchung," 2004, retrieved on 11-12-2012, retrieved from http://www.bfu-web.de/nn_41670/DE/Publikationen/Untersuchungsberichte/2002/Bericht__02__AX001-1-2,templateId=raw,property=publicationFile.pdf/Bericht_02_AX001-1-2.pdf.

[42] R. Parasuraman, and V. Riley, "Humans and automation: use, misuse, disuse, abuse," Human Factors, vol. 39(2), 1997, pp. 230–253.

[43] E. N. H. Montague, B. M. Kleiner, and W. W. Winchester III, "Empirically understanding trust in medical technology," International Journal of Industrial Ergonomics, 2009, doi:10.1016/j.ergon.2009.01.004.

[44] B. M. Muir, "Trust in automation: I. Theoretical issues in the study of trust and human intervention in automated systems," Ergonomics, vol. 37(11), 1994, pp. 1905–1922.

[45] M. Callon, "Some elements of a sociology of translation: Domestication of the scallops and the fishermen of St Brieuc Bay," in "Power, Action and Belief: a new Sociology of Knowledge? Sociological Review Monograph," J. Law, Ed., London, 1986, pp. 196-233.

[46] B. Latour, "Science in Action: How to Follow Scientists and Engineers Through Society," Milton Keynes, 1987.

[47] S. Timmons, R. Harrison-Paul, and B. Crosbie, "How do lay people come to trust the Automatic External Defibrillator?," Health, Risk & Society, vol. 10(3), 2008, pp. 207-220.

[48] E. N. H. Montague, and B. M. Kleiner, "Using variance analysis to detect mismatches in role expectations in patient physician interactions in obstetric work systems," Paper presented at the 2009 International Ergonomics Association, Beijing, China, 2009.

[49] H. W. Hendrick, and B. M. Kleiner, "Macroergonomics: An introduction to work system design," Santa Monica, CA: Human Factors and Ergonomics Society, 2001.

[50] ThomsonReuters, "Web of Science," 2011, retrieved on 06-27-2011, retrieved from http://thomsonreuters.com/products_services/science/science_products/a-z/web_of_science/.

[51] PubMed, 2011, retrieved on 12-11-2012, retrieved from http://www.ncbi.nlm.nih.gov/pubmed.

[52] PsycINFO, 2011, retrieved on 12-11-2012, retrieved from http://www.apa.org/pubs/databases/psycinfo/index.aspx.

[53] G. Abe, and J. Richardson, "Alarm timing, trust and driver expectation for forward collision warning systems," Applied Ergonomics, vol. 37, 2006, pp. 577-586.

[54] J. S. Chugh, and J. K. Caird, "In-Vehicle Train Warnings (ITW): The Effect of Reliability and Failure Type on Driver Perception Response Time and Trust," in Human Factors and Ergonomics Society 43rd Annual Meeting, Houston, TX, 1999.

[55] B. H. Kantowitz, R. J. Hanowski, and S. C. Kantowitz, "Driver acceptance of unreliable traffic information in familiar and unfamiliar settings," Human Factors, vol. 39, 1997, pp. 164–176.

[56] M. N. Lees, and J. D. Lee, "The influence of distraction and driving context on driver response to imperfect collision warning systems," Ergonomics, vol. 50(8), 2007, pp. 1264–1286.

[57] N. A. Stanton, and M. S. Young, "Driver behaviour with adaptive cruise control," Ergonomics, vol. 48(10), 2005, pp. 1294- 1313.

[58] N. Bagheri, and G. Jamieson, "The impact of context-related reliability on automation failure detection and scanning behavior systems," Proceedings of the 2004 IEEE International Conference, Man and Cybernetics, vol. 1 (10–13), 2004, pp. 212-217.

[59] J. P. Bliss, and M. C. Dunn, "Behavioural implications of alarm mistrust as a function of task workload," Ergonomics, vol. 43(9), 2000, pp. 1283-1300.

[60] J. S. Hughes, S. Rice, D. Trafimow, and K. D. Clayton, "The automated cockpit: A comparison of attitudes towards human

and automated pilots," in Transportation Research, vol. F12(5), 2009, pp. 428-439.

[61] A. Keller, and S. Rice, "System-Wide versus Component-Specific Trust Using Multiple Aids," The Journal of General Psychology, vol. 137(1), 2010, pp. 114–128.

[62] A. J. Masalonis et al., "Air traffic controller trust in a conflict probe during Free Flights," Paper presented at the 42nd Annual Meeting of the Human Factors and Ergonomics Society, Santa Monica, CA, 1998.

[63] J. M. McGuirl, and N. B. Sarter, "Supporting trust calibration and the effective use of decision aids by presenting dynamic system confidence information," Human Factors, vol. 48(4), 2006, pp. 656–665.

[64] S. Rice, and K. Geels, "Using System-Wide Trust Theory to Make Predictions About Dependence on Four Diagnostic Aids," The Journal of General Psychology, vol. 137(4), 2010, pp. 362-375.

[65] C. D. Wickens et al., "False alerts in air traffic control conflict alerting system: Is there a "cry wolf" effect?," Human Factors, vol. 51(4), 2009, pp. 446-462.

[66] M. T. Dzindolet, L. G. Pierce, H. P. Beck, and L. A. Dawe, "The perceived utility of human and automated aids in a visual detection task," Human Factors, vol. 44, 2002, pp. 79–94.

[67] S. Rice, "Examining single- and multiple-process theories of trust in automation," The Journal of general psychology, vol. 136(3), 2009, pp. 303-319.

[68] S. Rice, K. D. Clayton, A. Wells, and D. Keller, "Manipulating Trust Behaviors in a Combat Identification Task," Workshop Human Factors Issues in Combat Identification, 2008.

[69] L. Wang, G. A. Jamieson, and J. G. Hollands, "Trust and Reliance on an Automated Combat Identification System," Human Factors, vol. 51(3), 2009, pp. 281-291.

[70] M. Yeh, and C. Wickens, "Display signaling in augmented reality: Effects of cue reliability and image realism on attention allocation and trust calibration," Human Factors, vol. 43(3), 2001, pp. 355-365.

[71] J. Y. Jian, A. M. Bisantz, and C. G. Drury, "Foundations for an empirically determined scale of trust in automated systems," International Journal of Cognitive Ergonomics, vol. 1(4), 2000, pp. 53-71.

[72] J. D. Lee, and K. A. See, "Trust in automation: Designing for appropriate reliance," Human Factors, vol. 46(1), 2004, pp. 50–80.

[73] P. Madhavan, and D. A. Wiegmann, "Similarities and differences between human–human and human–automation trust: an integrative review," Theoretical Issues in Ergonomics Science, vol. 8(4), 2007, pp. 277–301.

[74] R. Parasuraman, and C. D. Wickens, "Humans: Still Vital After All These Years of Automation," Human Factors, vol. 50(3), 2008, pp. 511–520.

[75] J. E. Bahner, A.-D. Hueper, and D. Manzey, "Misuse of automated decision aids: Complacency, automation bias and the impact of training experience," International Journal of Human-Computer Studies, vol. 66, 2008, pp. 688–699.

[76] S. M. Merritt, and D. R. Ilgen, "Not all trust is created equal: dispositional and history-based trust in human-automation interactions," Human Factors, vol. 50(2), 2008, pp. 194-210.

[77] N. Moray, T. Inagaki, and M. Itoh, "Adaptive automation, trust, and self-confidence in fault management of time-critical tasks," Journal of experimental psychology, vol. 6(1), 2000, pp. 44-58.

[78] D. A. Wiegmann, A. Rich, and H. Zhang, "Automated diagnostic aids: The effects of aid reliability on users' trust and reliance," Theoretical Issues in Ergonomics Science, vol. 2(4), 2001, pp. 352–367.

[79] G. Ho, L. M. Kiff, T. Plocher, and K. Z. Haigh, "A model of trust and reliance of automation technology for older users," Papers of the AAAI Fall Symposium "Caring Machines: AI in Eldercare," Menlo Park, CA, 2005, pp. 45-50.

[80] G. Ho, D. Wheatley, and C. T. Scialfa, "Age differences in trust and reliance of a medication management system," Interacting with Computers, vol. 17, 2005, pp. 690–710.

[81] C. A. Miller, K. Haigh, and W. Dewing, "First, cause no harm: Issues in building safe, reliable and trustworthy elder care systems," Proceedings of the AAAI-02 Workshop "Automation as Caregiver", 2002.

[82] E. N. H. Montague, "Patient source of learning about health technologies and ratings of trust in technologies used in their care," Ergonomics, vol. 53(11), 2010, pp. 1302–1310.

[83] E. N. H. Montague, "Validation of a trust in medical technology instrument," Applied Ergonomics, 2010, doi:10.1016/j.apergo.2010.01.009

[84] K. Shea, and J. A. Effken, "Enhancing Patients' Trust in the Virtual Home Healthcare Nurse," Computers, Informatics, Nursing, vol. 26(3), 2008, pp. 135–141.

[85] N. Ezer, A. D. Fisk, and W. A. Rogers, "Age-Related Differences in Reliance Behavior Attributable to Costs Within a Human-Decision Aid System," Human Factors, vol. 50(6), 2008, pp. 853-863.

[86] C. A. Miller, "Trust in adaptive automation: the role of etiquette in tuning trust via analogic and affective methods," Proceedings of the First International Conference on Augmented Cognition, Las Vegas, NV, 2005.

[87] B. Rajaonah, F. Anceaux, and F. Vienne, "Trust and the use of adaptive cruise control: a study of a cut-in situation," Cognition, Technology & Work, vol. 8(2), 2006, pp. 146-155.

[88] I. Dassonville, D. Jolly, and A. M. Desodt, "Trust between Man and Machine in a Teleoperation System," Reliability Engineering and System Safety, vol. 53(3), 1996, pp. 319-325.

[89] X. Jiang et al., "Measurement of human trust in a hybrid inspection system based on signal detection theory measures," in International Journal of Industrial Ergonomics, vol. 34, 2004, pp. 407-419.

[90] B.-M. Wälivaara, S. Andersson, and K. Axelsson, "Views on technology among people in need of health care at home," International Journal of Circumpolar Health, vol. 68(2), 2009, pp. 158-169.

[91] M. Calnan, D. Montaner, and R. Horne, "How acceptable are innovative health-care technologies? A survey of public beliefs and attitudes in England and Wales," Social Science & Medicine, vol. 60, 2005, pp. 1937–1948.

[92] Y. J. Tenney, W. H. Rogers, and R. W. Pew, "Pilot opinions on cockpit automation issues," International Journal of Aviation Psychology, vol. 8, 1998, pp. 103–120.

[93] B. M. Muir, and N. Moray, "Trust in automation. Part II. Experimental studies of trust and human intervention in a process control simulation," Ergonomics, vol. 39(3), 1996, pp. 429-460.

[94] R. Parasuraman, and D. Manzey, "Complacency and bias in human use of automation: An attentional integration," Human Factors, vol. 52(3), 2010, pp. 381-410.

[95] J. Sanchez, G. Calcaterra, and Q. Q. Tran, "Automation in the home: The development of an appropriate system representation and its effects on reliance," Proceedings of the Human Factors and Ergonomics Society 49th annual meeting, 2005.

[96] J. F. Coughlin, L. A. D'Ambrosio, B. Reimer, and M. R. Pratt, "Older Adult Perceptions of Smart Home Technologies: Implications for Research, Policy & Market Innovations in Healthcare," Proceedings of the Engineering in Medicine & Biology Annual Conference IEEE, Lyon, 2007.

[97] C. Harrefors, K. Axelsson, and S. Sävenstedt, "Using assistive technology services at differing levels of care: healthy older couples' perceptions," Journal of Advanced Nursing, vol. 66(7), 2010, pp. 1523–1532.

[98] Y. Jasemian, "Elderly comfort and compliance to modern telemedicine system at home," Proceedings of the Second International Conference on Pervasive Computing Technologies for Healthcare, PervasiveHealth 2008, Tampere, 2008.

[99] M.-L. Jung, and K. Loria, "Acceptance of Swedish e-health services," in Journal of Multidisciplinary Healthcare, vol. 3, 2010, pp. 55–63.

[100] J. F. Coughlin, J. Lau, L. Ambrosio, and B. Reimer, "Adult children's perceptions of intelligent home systems in the care of elderly parents," Proceedings of the 3rd International Convention on Rehabilitation Engineering & Assistive Technology, 2009.

[101] tns emnid, "Wohnwünsche im Alter," Grafikreport, Januar 2011, retrieved on 11-12-2012, retrieved from http://www.bfw-bund.de/uploads/media/Emnid_Wohnw%C3%BCnsche_im_Alter_-_Pressemappe.pdf.

RESEARCH ARTICLE 2

Steinke, F., Bading, N., Fritsch, T., & Simonsen, S. (2014). Factors influencing trust in Ambient Assisted Living technology: A scenario-based analysis. *Gerontechnology, 12,* 81-100.

Factors influencing trust in Ambient Assisted Living Technology: A scenario-based analysis

Frederick Steinke MSc[a]
Nicole Bading MSc[b]
Tobias Fritsch PhD[c]
Svenja Simonsen MSc[b]

[a]Humboldt Universität zu Berlin, Berlin, Germany; E: steinkef@student.hu-berlin.de; [b]Ernst-Moritz-Arndt-Universität Greifswald, Greifswald, Germany; [c]Ruprecht-Karls-Universität Heidelberg, Heidelberg, Germany

F. Steinke, N. Bading, T. Fritsch, S. Simonsen, Factors influencing trust in Ambient Assisted Living Technology: A scenario-based analysis. Gerontechnology 2014;12(2):81-100
doi:10.4017/gt.2013.12.2.002.00
Demographic aging in Germany and the related structural change in the health care sector enable a market for assistive technologies for elderly people in a home living environment. The objective of this study is a scenario-based analysis regarding trust in Ambient Assisted Living (AAL). A standardized questionnaire survey with 292 participants from 50 to 93 years of age was conducted in Germany. Two different interview groups, people who need support in daily life due to different kinds of impairment and people without need for care, have been considered. The analysis was using correlation and stepwise regression analysis. As an important finding, a strong relationship between trust in AAL and an intention to use AAL can be highlighted. The significant influencing factors on trust are expected reliability, perceived ease of use, and perceived usefulness of AAL. Information procurement, interest in technology, and perceived health status are further variables which directly influence the end-user intention to use. People with need for care showed lower trust and intention to use values than people without need for care. The analyses show additionally that younger as well as participants with better perceived health status have higher trust values and more intention to use AAL based on the two scenarios. In contrast to a former study in the AAL context, gender has no significant influence on trust. In the future, further experimental studies with focus on elderly persons' trust in AAL will be performed. These experiments will include, on the one hand, personal remote assistance for the end-user and, on the other hand, variation of actual reliability of AAL technology.

Keywords: AAL, ambient assisted living, assistive technology, older adults, trust

Demographic aging is one of the biggest challenges for society and economy worldwide[1]. In particular, Germany is affected by an aging population. In 2011, Germany has the highest percentage rate of persons aged 65 years and older within the European Union[2]. At the same time, the number of people needing care and the associated demand for home care services will increase continuously. This development is amongst others caused by the desire of more than 80% of elderly people who want to remain in their familiar surroundings despite age-related limitations and diseases[3]. Simultaneously, the effects of demographic change linked with a declining number of working people will be perceptible in the care sector. Accordingly, the increasing demand for appropriate care with home care services stands in contradiction to an acute shortage of qualified nurses[4].

Against this background in ambulatory health care, new services are needed. These services should be equipped to respond to the changing demands of elderly people to meet the highest level of autonomy and quality of care in their own homes. Beyond that, these services should also consider the future social and economic changes. Ambient Assisted Living (AAL) describes the development of concepts, products and services, using innovative information and communication technologies, to ensure and increase the quality of the users' life[5]. In outpatient care, age-appropriate, intelligent assistance systems in combination with local help services can be useful for elderly persons in need of assistance and nursing care to achieve a longer and even more self-determined life and ensure the quality of care in their familiar home environment. "The AAL domain concentrates on innovative utilization of ICT [Information and Communication Technologies], new ways of user interaction or new types of value chains for independent living services"[6]. ICT-based solutions offer a wide spectrum, beginning with the usage of social media technologies via television, tablet computer or smartphone, to strengthen social interaction and relationships[7-9]. Self-management by measuring physiological parameters such as

blood pressure and body weight at home with the aim of an application is supported by an AAL solution[10]. Also, biologically inspired stereo vision sensors and the development of algorithms for the detection of falls in the home environment belong to the area of AAL technology[11].

In addition, the use of AAL technologies by caregivers may have a supporting or relieving effect, and contributes to a cost reduction in the health and care system. To ensure the success of AAL technologies and systems, besides economic and technical aspects, the needs of the user group and several barriers need to be considered[12,13]. Furthermore, end-user trust will play a significant role in the success and use of intelligent assistance systems. For this purpose, it is essential to explore and eliminate the barriers of trust and intention to use AAL.

In this context, the present article answers the research question: What are the main determinants affecting end-users' trust in AAL systems and intention to use? To answer this question, the article is structured as follows: The background section considers the influence of demographic aging and the growing importance of technology-based support as given by AAL. Additionally, trust in automation is presented and a brief description of the Technology Acceptance Model (TAM) is given. Subsequently, the derivation of the hypotheses as well as the methodology section, including questionnaire construction, pre-test information, scale description, and sampling and procedure details, is demonstrated. Descriptive statistics, correlation and regression analysis can be found in the results section. Finally, a comprehensive discussion including hypotheses verification as well as conclusion, limitations and a presentation of further research round the article.

Background

This section starts with information about the development of AAL as a reaction to demographic aging and the care level classification according to German law. Furthermore, an introduction of trust in automation and TAM is given.

Demography and AAL

Over the past four decades, the demographic change in Germany and its impact on society and the economy have become increasingly important. This development results from the steady increase in life expectancy and a stagnating low-level fertility rate[14]. According to the German Federal Statistical Office, a population decline of up to 17 million people (20%) is expected for Germany by the year 2060. In addition to that, the low birth rate and rising life expectancy lead to a demographic shift of the population. Thus, the proportion of people aged 65 and older will increase from almost 20% in 2008 to about 29% in 2030. Following this forecast, one of three people will be aged 65 and above in 2060[15].

Changes of the age structure also have an impact on the proportion of the working population and, thus, on the German health system. In future, growing health care expenditures due to the increasing demand for health services, especially for older people, are expected[14,16]. In 2007, 5% of people aged between 70 and 74 years were in need of care, whereas 62% of people aged over 90 years were needy. In view of the aging society, a rise in long-term care is anticipated[17]. By definition of the German Federal Ministry of Health, people with need for care are assigned to one of three care levels depending on the extent of assistance. According to the German care law, persons of all ages who need permanent or at least six months of substantial assistance in personal hygiene, nutrition, mobility, and domestic help are in need of care[18].

Care level 1 (CL1) can be defined as the existence of considerable nursing care. More precisely, at least once daily, support in two or more tasks in (one or more) areas of basic care (personal hygiene, nutrition and mobility) is necessary. In addition, several times a week, support in domestic help is required. A daily average of at least 90 minutes for assistance including not less than 45 minutes for basic care occurs in CL1. In care level 2, however, personal help in basic care is needed at least three times a day. Moreover, the time spent per week amounts to a daily average of at least three hours (including two hours for basis care). Care level 3 (CL3) exists for persons who require full-time assistance, including nightly support. At least four hours of support in basic care on daily average and five hours in total will be allocated for CL3. In addition, domestic help is required several times a week in CL2 and CL3[19].

The majority of people needing care want to stay in their familiar surroundings as long as possible. In order to postpone or avoid a transfer to a residential care facility, seniors prefer to be supported by outpatient services in their own households. In 2007, 68% of the dependants in Germany were supplied at home[17]. Housing is one of the basic needs of human beings. Because of physical and mental impairments or diseases, elderly people are often reduced in their mobility. This has the consequence that the environment of individuals aged 65 years and older is largely confined to their home and direct neighborhood[12,20]. The need for age-designed homes

continues to increase[21-23]. In addition to structural alterations of housing stock and the creation of a barrier-free living environment, new technologies open the potential to increase the autonomy of the elderly. "AAL refers to intelligent systems of assistance for a better, healthier and safer life in the preferred living environment and covers concepts, products and services that interlink and improve new technologies and the social environment"[24] . Furthermore, several other definitions of AAL exist[25-27].

AAL applications are based on the use of modern information and communication technologies (e.g., sensors and actuators, wireless LAN, applications) in the immediate life and living environment of the end-user. By adapting the system to the specific needs of its users, AAL applications aim at improving the quality of life, irrespective of age and context of use[28]. In addition, AAL systems contribute to the compensation of health-related restrictions and shall allow a self-determined life. To counteract loneliness in old age, AAL solutions are developed to improve social interaction and participation[29].

The target group for AAL usage is very heterogeneous[30]. The Ambient Assisted Living Joint Programme categorized end-users into primary, secondary and tertiary users[31]. The primary end-user is actually using the AAL technology and benefits by an increasing quality of life. Persons or organizations which are directly in contact with the primary end-user (e.g., family members, friends, care organizations or neighbors) are called secondary end-users. Private or public organizations and institutions (e.g., public sector service organizers, insurance companies or social security systems) are tertiary end-users of AAL. This type of end-user is not directly using AAL but benefits "from increased efficiency and effectiveness which result in saving expenses or by not having to increase expenses in the mid and long term"[31].

AAL can ensure an adequate supply to improve health care systems in the health sector as well as costs savings[32]. AAL is characterized by a high degree of complexity that results from the different needs of users. This complexity is not tangible for the end-user, as only the visible user interface is necessary for using. Despite of that, the user has to trust that AAL technology works reliably.

Trust in automation

The core function of trust should be the reduction of complexity and uncertainty despite a lack of information. Trust enables the capacity to act in risky and uncertain situations[33]. In addition, trust plays an important role in overcoming the perceived risks and uncertainties associated with the use of new technologies[34]. Against this background, trust seems fundamentally important, especially in the course of increasing environmental complexity and uncertainty. As seen by Lee and See: "Trust in automation guides reliance when the complexity of the automation makes a complete understanding impractical"[35].

In addition, the calibration of trust plays an essential role in the use of automation[35]. Several studies have shown that people are more willing to rely on automation they trust and reject automation they distrust[35,36]. Thus, according to Lee and Moray[37,38], the use of automation is positively influenced by users' trust. Moreover, it should be added that individual differences in personality and perception mediate the connection between characteristics of a machine and users' trust[39]. Unless the user is not aware of the true performance of the system, overreliance, rejection of technology, as well as improper use are possible outcomes[40]. Research shows that trust perceptions vary quite dramatically as a function of reliability[41].

Various areas have a long tradition in research of automated systems and trust. Trust in automotive[42-44], aviation[45-47], combat identification[48-50], supervisory control systems[37,51,52] or human-robot interaction (HRI)[52-54] is a focus of attention in science. In contrast, trust in medical technology, and especially AAL, is still in its infancy. By performing a literature review, a large number of factors within studies regarding trust in healthcare and assistance systems can be identified[50]. Besides trust, technology characteristics like reliability, ease of use or perceived usefulness were detected and need to be analyzed in more detail.

Due to the high degree of complexity and the fact that in crucial situations like falls or fire AAL is installed to rescue a person's life, end-users' presence of trust is essential. "Trust in Ambient Assisted Living (AAL) can be defined as the attitude that an assistive technology supports an impaired person within [its] social environment in an uncertain and vulnerable situation"[55].

The success of new technologies in terms of use behavior depends on technological and trust issues[56]. A previous requirement analysis of 50 elderly people in the AAL context revealed high trust values, especially for sensors in the accommodation. Moreover, the constructs of reliability and perceived ease of use were mentioned by the elderly as highly important for the existence of trust in AAL[57]. Following these results as well as the knowledge of the literature review, the variables of the TAM[58] seem to have an influence on trust in AAL. For this reason the TAM

and further developments are introduced and afterwards used to build the hypotheses.

Technology Acceptance Model

The Technology Acceptance Model (TAM) was developed by Davis[58] and addresses the assumption that user acceptance is the crucial factor for success of new information systems. TAM is also evolved to provide implications for practitioners regarding the design of system characteristics in order to improve user acceptance[59]. Aligned with the Theory of Reasoned Action (TRA) which was proposed by Fishbein and Ajzen[60], the model examines the causal relationships between external stimuli, cognitive response, affective response, and behavioral response. It specifies perceived usefulness and perceived ease of use as the two most important determinants of user acceptance[61]. As defined by Davis[61], perceived usefulness is an indicator for the extent of job performance improvement perceived by a person who applies the new system. Perceived ease of use, however, measures the degree to which the person assumes that the new information system can be used nearly without effort. Both factors determine the attitude toward using the system. For the definition of the attitude toward using, principles from the TRA are employed[60]. According to the authors' findings, attitude toward using measures "the degree of evaluative affect that an individual associates with using the target system in his or her job"[59]. The attitude toward usage affects the behavioral intention to use, which leads to actual usage. The model not only confirms direct causal effects which external stimuli have on perceived usefulness, perceived ease of use, and attitude toward using, but also specifies a significant impact of perceived ease of use on perceived usefulness. Instead, usefulness does not influence ease of use, but rather the behavioral intention to use[62]. However, caution should be exercised by interpreting the results of the model because it is an instrument to measure perceived use and not actual usage[63,64].

The TAM was developed over time and has been applied and modified in different application fields[65-67]. For example, Hu et al. [68] examined the applicability of the TAM in explaining physicians' decisions to accept telemedicine technology in a health care context. Pavlou[56] and Grefen et al. [69] applied the TAM in the field of electronic commerce and modified the model by integrating trust issues. Additionally, the Unified Theory of Acceptance and Use of Technology (UTAUT) developed by Venkatesh et al. [70] assessed eight theoretical models which focused on intention to use respectively, with usage being the dependent variable. In context of assistive social agent technology, the UTAUT was used for testing the acceptance of older people[71]. The present study is not aimed at a further development of TAM or UTAUT. Instead, the trust factor is at the center of interest in this investigation. The aim is to highlight the influence of variables on trust of older people in AAL technology and also to assess the impact on the intention to use. For that purpose, both variables of the TAM and additional variables are used. These variables are explained as follows.

Hypothesis development

The present study analyzes different influencing factors on trust in AAL technology (T_{AAL}) and intention to use (IU). Various demographics and personal factors as well as the differentiation between persons with care level 1 (CL1) and without care level (WCL) have been considered.

First of all, the interconnection between T_{AAL} and IU will be clarified by means of the main hypothesis (H1). These two variables are then examined by the split into the CL1 and WCL groups. Afterwards, eight further variables are introduced and taken into account for the consideration of T_{AAL}. To begin with, the three variables chronological age (CA), perceived health status (PHS) and gender (G) are considered. Additionally, the external variables perceived usefulness (PU), perceived ease of use (PEOU), expected reliability (ER), interest in technology (IT), and information procurement (IP) are investigated.

Intention to use (IU)

Intention to use as a variable is adapted from the TAM variable behavioral intention to use and upstream to the actual system use[61]. Intention to use AAL technologies characterizes the determination of a person to use the technology. The usage of AAL is a joint target for developers and service providers. As seen before, three different end-user types participate in actual usage of AAL. Altogether, multiple variables cause the actual usage. Within this study, the importance of primary end-users' trust in AAL will be analyzed. The construct of trust itself is influenced by further variables which are presented in detail afterwards. Summarizing, it can be expected that if an impaired person trusts an assistive technology, there will be a higher intention to use. Therefore, the main hypothesis can be stated:

H1. *Intention to use is positively influenced by trust in AAL technology.*

Care Level 1 (CL1)

Persons with physical, mental or psychological illness or disability can be assigned to care levels 1 to 3[18]. As defined by BMG, people who need

support in domestic help several times a week and, furthermore, assistance in areas of basic care such as personal hygiene, nutrition and mobility for at least 45 minutes per day might apply for CL1[19]. As seen, persons with CL1 have different kinds of impairments and form a heterogeneous group, but everyone with CL1 is receiving support in daily life. This fact is accompanied by an awareness of support. People with CL1 know about the importance of personal care and are able to imagine how technological assistance could improve their housing situation. Thus, the second hypothesis to be tested is:

H2. *Trust (a) and intention to use (b) are positively influenced by care level 1.*

Chronological age (CA)
Chronological age means age measured by the date of birth, which can differ from biological, psychological or social age[72]. In literature, the elderly are often divided into third and fourth age[73-76] or into terms such as young-old, old-old as well as very-old or oldest-old[77-80]. Additional to these distinctions, cohort effects influence social age. As seen in Robinson and Jackson, a nonlinear cohort effect seems to exist in the United States. Trust increases from younger to middle age and then stabilizes[81].

The process of aging is often associated with stigma to disease and, consequently, with loss of independence. Technical solutions raise awareness of one's disability. Thus, older people are often reluctant to admit their disability and, therefore, reject technological innovations. Moreover, one can expect that lack of technical knowledge reinforces the mentioned anxieties. Therefore, an introduction in new technologies by personal assistance or an age-appropriate manual is useful. As seen in various studies, elderly people rather trust in technological devices compared to younger people[82-85]. Regarding the complexity and, thus, the necessity of older persons' trust in automation, it can be assumed that:

H3. *Trust in AAL technology (a) as well as intention to use (b) are positively influenced by chronological age.*

Perceived health status (PHS)
"Health is a state of complete physical, mental and social well-being and not merely absence of disease"[86]. The perceived health status designated the individual's perception of health. Preservation of health and the associated long life at home is a basic need which cannot be achieved without support from many people. Technical support by AAL systems offers a possibility for a self-determined life in a home environment. Dependent on the current perceived health status, elderly people have the ability to deal with new technology or to get help from their relatives. For people with a lower perceived health status, trust in other people who provide care as well as assistive technology is gaining importance. Therefore, the following hypothesis can be suggested:

H4. *Trust (a) and intention to use (b) are negatively influenced by the perceived health status.*

Gender (G)
The next variable - gender - could be of interest in the development of AAL technology. Due to the fact that women have a higher life expectancy than men and more often live alone in old age[87], AAL should be designed considering female special demands. Despite this fact, Steinke et al.[57] found out which men have higher trust scores in AAL sensors than women. Following this former result, the next hypothesis can be assumed:

H5. *Trust (a) and intention to use (b) are positively influenced by the male gender.*

Perceived ease of use (PEOU)
Perceived ease of use is "the degree to which a person believes that using a particular system would be free of effort"[61]. End-users who have little or no experience with technical devices need an understandable and user-friendly design to build trust. The appearance of technology, an understandable manual or self-explanatory device as well as the personification of interfaces increase technological trust[88-90]. Moreover, positive automation etiquette[45] and notes during the usage of the technology may intensify technological trust[50,91,92]. An example could be a green lamp which signalizes the correct functionality of the device. Based on the existing literature, the hypothesis is set up as follows:

H6. *Trust in AAL technology is positively influenced by perceived ease of use.*

Perceived usefulness (PU)
The next variable, which also results from the TAM, is perceived usefulness. According to Davis[61], perceived usefulness is defined as "the degree to which a person believes that using a particular system would enhance his or her job performance". In the original TAM, perceived usefulness is significantly influenced by PEOU, but not vice versa. As noticed by Pohlmeyer [93], the perceived usefulness of a computer system is the main factor for elderly persons to use the system. In context of AAL, perceived usefulness is reflected by the chance for a longer and more independent life at home as well as a higher

quality of living. Following these ideas, H7 can be suggested:

H7. *Trust in AAL technology is positively influenced by perceived usefulness.*

Expected reliability (ER)
Perceived reliability of an automation influences trust in technologies[51,89,90,94,95]. End-user perception of the device's function depends on the number of occurred errors and often differs from the actual reliability of the technology. Actual reliability describes the actual performance of the technology[96-101]. Within this study, reliability should be considered expected reliability[102]. In case of medical and emergency support systems, a perfect actual reliability of the technology would be preferable in case of an emergency.

H8. *Trust in AAL technology is positively influenced by expected reliability.*

Interest and Information Procurement (IP)
The variable interest in technology (IT) describes whether the elderly enjoy testing or like to possess (new) electronic devices (*Appendix 1*). The importance of ICT in everyday life and within AAL technology ascends[6]. The study by Sayago and Blat[103] focused on everyday e-mail usage of about 400 elderly people. The key elements for e-mail usage are socialization, inclusion, and independence. The interest of using a technology additionally depends on personal interest, particularly on social circles which use the technology as well. As a well-known example, the introduction of the telephone saw interest of each person rise with an increasing number of end-users. People who are more interested in new technologies tend to use AAL technology.

The term information procurement (IP) in this paper reflects the needs of inexperienced users, to obtain information on new technologies. The additional information gained by information procurement should allow a better understanding of the product. Depending on the consequences of a wrong decision, the user "has to weigh the costs and benefits of information procurement"[104] to make a proper decision. People who are not informed about AAL technology can use various sources like friends and relatives to get informed. Summarizing, people who tend to ask their friends and relatives before purchasing new technology seem to have a higher intention to use. Thus, the last hypothesis is:

H9. *Intention to use is positively influenced by (a) interest in technology and (b) information procurement.*

Methodology

As stated above, end-user trust could play a significant role in the success and use of intelligent assistance systems. The present study attempts to determine which factors affect T_{AAL} as well as IU.

Questionnaire construction
The questionnaire considers the different influence factors on T_{AAL} and IU, which are specified in the hypotheses. The questionnaire was especially designed for a survey with the elderly. Since participants with a care level and more than 80 years old were targeted for the survey, the items from the original scales needed to be reduced with consideration of reliability and variance values. Otherwise not all influence factors could have been investigated due to the long duration which would have been unreasonable for the participants. For this reason a focus group discussion was conducted to evaluate the existing constructs. The adapted questionnaire with a total of approximately 50 questions was tested in a pre-test with older people without a care level.

The items of all scales were adjusted by using seven-point Likert-type scales. Items on the scales are anchored at 1=strongly disagree, 2=moderately disagree, 3=somewhat disagree, 4=neutral (neither disagree nor agree), 5=somewhat agree, 6=moderately agree, and 7=strongly agree. The questionnaire also collected demographic data. Nearly all scales were translated from English into German and the tense of the items was changed.

The questionnaire was supported by two different scenarios in a domestic environment in order to illustrate the topic for respondents. The scenario technique is used as a standard method for usability testing[105]. The questionnaire was designed and used in German language.

The first scenario describes an emergency situation in a household in which a person falls in his accommodation, hurts his hip and cannot stand up by himself anymore. The installed AAL technology (combination of sensors and a smartphone application) is presented as a solution to the emergency case. The second scenario describes a situation in an accommodation in which a person forgets to turn off the stove and gets reminded by the AAL technology (*Appendix 2*).

Pre-test
In March 2012, a pre-test with 64 persons aged 40 to 90 years was carried out to test the questionnaire. Participants were recruited through home care services. Participants' average age was 63.28 (SD=10.03; range=40–90). The majority of 44 respondents (69.8%) were female and a minority of 19 respondents (29.7%) male.

One person (1.6%) did not respond to this question. With respect to the housing situation, 16 respondents (25.0%) were living alone, while 48 respondents (75.0%) were living together with other persons.

The results of the pre-test showed medium to very high Cronbach Alpha values' for all scales ranging from 0.748 to 0.976. The percentage of explained variances in the principal component analysis (PCA) of the eight scales lay between 57.3% (PHS) and 92.5% (IU). Six calculated percentage variances could be assigned to the Kaiser-Meyer-Olkin (KMO) measure with values above 0.7 ('moderate to good' defined by Kaiser and Rice[106]). Two calculated percentage variances (PHS and PEOU) showed moderate to poor values between 0.5 and 0.69.

As a result of the pre-test, linguistic adaptions and a more substantial instruction of the questionnaire were made. The response format was supplemented by a 'don't know' box. Slight modifications of three scales have been made.

Scale description

The scale for T_{AAL} was adapted from Jian et al.[107]. The authors originally identified 12 potential factors of trust between people and automated systems and used these factors to develop a scale in order to measure trust in automation. Prior research in trust and automation indicated that the scale was particularly suitable for adaption in the AAL context. Seven items that represent trust in AAL technology were selected. After the pre-test, two items — "The system behaves in an underhanded manner" and "The system has integrity" — were removed from the scale, so that five items for T_{AAL} finally remained.

The construct for IU as a predictor of actual usage is based on Kornmeier[108]. The author analyzed influence factors on the acceptance of mobile communication-based payment systems. The original questionnaire comprised six indicators which were reduced to three items in the context of AAL. The only linguistic adjustment was the change of the target object by the term 'assistive technology'.

The scales PEOU and PU were based on the scales by Davis[61]. The initial scale items for PEOU contained 14 items. Half of the items turned out to be unsuitable to describe the AAL technology and have been removed for this reason. The remaining seven items were modified to suit the context of the study, e.g., the target object was changed from electronic mail system to assistive technology. No need for adjustments was indicated by the pre-test.

The original PU scale also contained 14 items. Just like the items of the PEOU scale, more than half of the items of the PU scale turned out to be unsuitable to describe AAL technology. For this reason only five items were remaining. These items were also modified to suit the context of AAL technology by changing the target object from electronic mail system to assistive technology. Furthermore, the scale was supplemented by two additional items regarding comfort and reputation after the pre-test.

The measure for ER was adapted from Montague[109]. The author developed and validated an instrument for measuring the patient's trust in medical technology. The initial scale comprised about 80 items. 31 items referred to the target object technology, with the other items including statements to health care providers. Only the sufficiently reliable items of these 31 items were included into the questionnaire. Thus, six items of those were selected and the target object was changed.

The scale measuring interest in technology (IT) is based on Karrer et al.[110]. A German questionnaire to obtain the user's handling of, and attitude toward electronic devices was developed. The questionnaire comprised a total of 19 items. Technical affinity is measured by four subscales. The subscales are enthusiasm in dealing with technology, subjective competence, perceived positive consequences of technology, and perceived negative consequences of technology. For the purposes of the present study, the scale enthusiasm in dealing with technology with five questions was selected and included in the questionnaire without further adjustments.

The scale for IP was adapted from Pütz[111]. The author examined the effects of word-of-mouth recommendations from wary recipients. To determine IP, the information procurement scale was considered suitable for the survey. Four of eight items were appropriate to determine technology knowledge. After the pre-test the wording was adjusted and an additional self-created item - "I generally buy only products that my friends or acquaintances buy" - was integrated as a control item.

The four items of the PHS scale were selected from the internationally accepted SF-36 Health Survey in German language[112]. The SF-36 is a multi-purpose, short-form health survey with 36 questions. The subscale 'general health' comprised five items which are appropriate for determining the participants' current perceived health status. Four out of these five subscale items were adapted without further adjustments to the questionnaire (*Appendix 1*).

Sampling and procedure

The actual questioning was carried out between April and June 2012. The survey included persons aged 50 years and older with and without care level 1. Afterwards, the sample was split into two groups. The first group included persons with care level 1 (CL1) and the second group persons without care level (WCL). For the purpose of the survey, persons with CL1 were selected exclusively, as these persons are less dependent on outside help in activities of daily living compared to persons with a higher care level. The participants were recruited through home care services, nursing homes, assisted-living residences, and senior clubs.

All statistical analysis was conducted using SPSS Statistics version 17.

Results

The following section describes the results of the survey. First, the descriptive statistics and validation of reliability and validity are presented. Afterwards, the findings of a correlation and regression analysis are shown.

Descriptive statistics

A total of 550 questionnaires were forwarded of which 292 participants (53%) completed the survey. Among the group CL1, 140 of 281 respondents (49%) finished the survey and 152 of 269 (56.5%) respondents of the group WCL.

The participants' average age was 74.4 (SD=10.0 median=75; range=50–93). Of the 292 respondents 190 were female (65.1%) and a minority of 95 respondents (32.5%) were male. Another 7 respondents (2.4%) left this field blank.

Among the group CL1, the number of female participants was 96 (70.1%) and that of male participants was 41 (29.9%).

A look at the sample split according to the need for care showed a slightly higher proportion of females and slightly lower proportion of males in group CL1 than in group WCL. Moreover, the persons with a need for care were on average about eight years older and lived almost twice as often alone compared to the WCL group (*Table 1*).

Validation of reliability and validity

The values of all measurement scales showed medium to very high reliability, with Cronbach's Alpha coefficient being between 0.719 and 0.961. It should be noted that the highest reliability coefficient belonged to the scale expected reliability and the lowest value to the PHS scale (*Table 2*). For verifying the validity of the individual scales also a PCA in the questionnaire study was performed. Within this PCA for T_{AAL} two factors with an eigenvalue of more than one could be extracted. Together these factors explained 78.9 % of the total variance. The loadings of the individual items on this factor ranged from 0.669 to 0.777. The scale IU reveals exactly one factor that explained 86.8 % of the variance. The factor loadings of the three items were between 0.906 and 0.951. Moreover, for both scales PEOU and ER one factor could be extracted. For PEOU the one factor explained 66.2 % (charges of the individual items on this factor ranging from 0.607 to 0.891) and for ER 83.8 % of the total variance (values between 0.871 and 0.948). The items of the scale PU all loaded on a single fac-

Table 1. Descriptive statistics of 140 participants in group CL1 (participants with care level 1) and 152 in group WCL (participants without care level)

Parameter		n		
		CL1	WCL	Total
Gender	Male	41	54	95
	Female	96	94	190
	Unknown	3	4	7
Education	No official Graduation	2	2	4
	Secondary school degree	71	58	129
	Intermediate school degree	42	44	86
	High school diploma	7	19	26
	University degree	13	22	35
	PhD	0	3	3
	Unknown	5	4	9
Profession	Technical	23	37	60
	Commercial	49	46	95
	Social / care	22	25	47
	Other	45	33	78
	Unknown	1	11	12
Housing	Alone	89	48	137
	With other persons	49	92	141
	Unknown	2	12	14
Smartphone owned	Yes	3	21	24
	No	136	127	263
	Unknown	1	4	5
Age	Mean±SD	78.2±9.5	70.9±9.1	74.4±10.0
	n Age known	139	148	287
	n Age unknown	1	4	5

Table 2. Cronbach's α and total variance explained of the eight scales used; T_{AAL}=Trust in AAL; PEOU=Perceived Ease of Use; PU=Perceived Usefulness; ER=Expected Reliability; IU=Intention to Use; IT=Interest in Technology; IP=Information Procurement; PHS=Perceived Health Status

Scale	Pre-test		Survey	
	α	Variance	α	Variance
PEOU	0.908	65.86	0.913	66.21
PU	0.965	87.79	0.927	73.32
ER	0.976	89.74	0.961	83.84
T_{AAL}	0.916	76.87	0.864	78.94
IU	0.959	92.50	0.924	86.79
IT	0.894	71.24	0.930	78.61
IP	0.867	75.50	0.914	74.85
PHS	0.748	57.30	0.719	54.51

tor which explained 73.3% of the total variance. The results of high reliability and validity were consistent with the results of the pre-test.

Correlation analysis

A correlation analysis has been conducted to obtain a first overview of the significant correlations between the variables, particularly of T_{AAL} and IU. The high correlations between the different variables indicate multicollinearity (*Table 3*). To identify multicollinearity between these variables and a causal connection, two stepwise regression analyses were conducted in the next step.

Regression analysis

The first analysis (*Table 4*) included PU, PEOU, ER, IT, IP, PHS, gender, age, and CL1 as predictors and T_{AAL} as the dependent variable. The results showed that only the variables ER (t=8.90, p<0.01), PEOU (t=4.46, p<0.1) and PU (t=2.48, p<0.05) were statistically significant. They explained 50.4% of the variance of the dependent variable T_{AAL} (adjusted R^2=0.504, p<0.01).

The second analysis (*Table 4*) included T_{AAL} and the variables IT, IP, PHS, gender, age, and CL1 as predictors and IU as the dependent variable. The results showed that the variables T_{AAL} (t=7.50, p<0.01), IT (t=5.98, p<0.01), IP (t=3.88, p<0.01), and PHS (t=-2.07, p<0.05) were statistically significant. They explained 40.1% of the variance of the dependent variable IU (adjusted R^2=.401, p=<o.01). The variables gender, age and CL1 were excluded due to the insignificant correlation with IU.

The connections between the variables and T_{AAL} as well as IU could be visualized (*Figure 1*).

Table 3. Correlation matrix of included parameters with two-tailed tests of significance; T_{AAL}=Trust in AAL; PEOU=Perceived Ease of Use; PU=Perceived Usefulness; ER=Expected Reliability; IU=Intention to Use; IT=Interest in Technology; IP=Information Procurement; PHS=Perceived Health Status; CL1=Care Level 1; HS=Housing situation; in bold: p<0.01; in italic: 0.01<p<0.05

	T_{AAL}	PEOU	PU	ER	IU	IT	IP	PHS	CL1	Male	Age
PEOU	**0.49**										
PU	**0.50**	**0.31**									
ER	**0.63**	**0.40**	**0.62**								
IU	**0.51**	**0.32**	**0.70**	**0.57**							
IT	**0.34**	**0.32**	**0.46**	**0.36**	**0.54**						
IP	-0.04	**-0.25**	**0.22**	0.08	**0.19**	*0.14*					
PHS	**0.20**	**0.25**	*0.14*	**0.24**	*0.13*	0.09	**-0.33**				
CL1	*-0.12*	*-0.12*	**-0.15**	-0.11	**-0.23**	**-0.27**	0.07	**-0.32**			
Male	-0.01	0.00	-0.05	-0.05	-0.04	**0.18**	0.04	-0.11	-0.07		
Age	**-0.20**	**-0.36**	-0.08	-0.08	-0.11	**-0.26**	**0.27**	**-0.27**	**0.39**	-0.04	
HS	0.12	**0.25**	0.06	-0.03	0.04	0.11	**-0.20**	**0.17**	**-0.30**	**0.23**	**-0.45**

Table 4. Stepwise regression in model 1 of T_{AAL} (Trust in AAL) and IU (Intention to Use); ER=Expected Reliability.; IP=Information Procurement; IT=Interest in Technology.; PEOU=Perceived Ease of Use; PHS=Perceived Health Status; PU=Perceived Usefulness

Predictor	Coefficients			t	p
	B	SD	ß		
DEPENDENT VARIABLE: T_{AAL} (TRUST IN AAL)					
(Constant)	1.136	0.254		4.47	0.000
ER_Mean	0.459	0.052	0.509	8.90	0.000
PEOU Mean	0.173	0.039	0.218	4.46	0.000
PU_Mean	0.125	0.050	0.135	2.48	0.014
DEPENDENT VARIABLE: IU (INTENTION TO USE)					
(Constant)	-0.015	0.459		-0.032	0.974
T_{AAL}_Mean	0.489	0.065	0.386	7.50	0.000
IT_Mean	0.304	0.051	0.308	5.98	0.000
IP_Mean	0.212	0.055	0.195	3.88	0.000
PHS_Mean	0.122	0.059	0.105	2.07	0.040

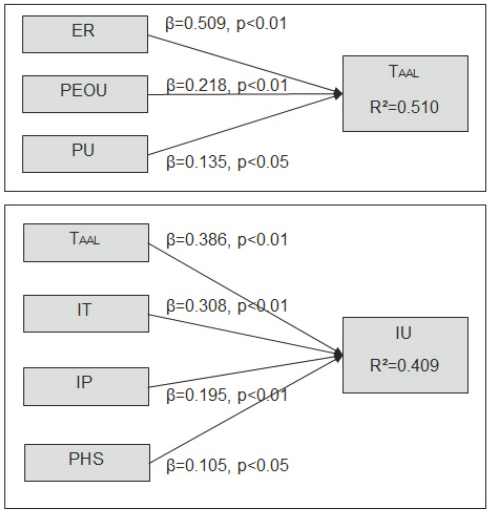


Figure 1. Visualization of the Regression Analysis on TAAL (Trust in AAL); ER=Expected Reliability; PEOU=Perceived Ease of Use; PU=Perceived Usefulness) and IU (Intention to Use; TAAL=Trust in AAL; IT=Interest in Technology; IP=Information Procurement; PHS=Perceived Health Status)

Discussion

First of all, it seems to be useful to visualize the outcomes of the hypothesis test for a structured interpretation (*Table 5*). With the aim of our hypotheses, the above-introduced research question - "What are the main determinants affecting end-users' trust in AAL systems and intention to use?" - will be answered.

Starting with the main hypothesis (H1), it can be clarified that there exists a strong significant positive relationship between trust in AAL technology and usage intention of the two described AAL solutions. As expected, elderly people who trust AAL are more willing to use the technology in a second step. This result is analogous to previous studies[56] which show a positive relation between these two constructs. Despite of these findings, it should be qualified that intention to use as a prediction is not automatically actual usage.

The next hypotheses regarding care level 1 (H2a; H2b), chronological age (H3a; H3b) and perceived health status (H4a; H4b) can be rejected. As seen in the results, the care level 1 factor has a significant negative correlation on trust and intention to use. This means that people without care level 1 have higher trust and an intention to use AAL technology. Moreover, younger participants and people with better perceived health status show higher trust and intention to use values. It should be mentioned that as seen by the descriptive statistics, the mean age of persons with care level 1 is nearly eight years higher than the group without a care level. The analysis revealed that chronological age is related to care level 1 and also with perceived health status. It can be expected that age, as integrated within these two variables, has an indirect influence on trust and intention to use. These results are contradictory not only to the hypotheses but also to the original idea of AAL. The present study highlighted that younger people with a better perceived health condition are more willing to use AAL.

Moreover, gender has no effect on either trust or on intention to use AAL. The previous results which show that men have higher trust in AAL sensors[57] cannot withstand in the larger sample. Thus, H5a and 5b can be rejected.

The three influencing factors perceived ease of use, perceived usefulness and expected reliability are positively connected with trust. Furthermore, hypotheses H6, H7 and H8 can be verified. Perceived ease of use is highly correlated with trust and the results are analogous to previous studies[56,57]. If older people have the feeling of an easy handling of the application, this can subserve building trust. Moreover, perceived usefulness by the AAL solution was positively influencing trust. In the original TAM[61], perceived usefulness was directly connected with intention to use. In this study, trust seems to serve as a mediator. Experimental studies need to investigate this connection further. Due to the importance of AAL for maintenance of health, it is comprehensible that

Table 5. Supported (is) and not-supported (is not) hypotheses on trust in AAL technology (TAAL) and the intention to use it (IU)

Parameter 1	Influence		On parameter 2	Hypothesis code
	positive	negative		
TAAL	is		Perceived ease of use	H6
	is		Perceived usefulness	H7
	is		Expected reliability	H8
	is not		Chronological age	H3a
	is not		Male gender	H5a
	is not		Care level 1	H2a
		is not	Perceived health status	H4a
IU	is		Trust in AAL	H1
	is		Interest in technology	H9a
	is		Information procurement	H9b
	is not		Chronological age	H3b
	is not		Male gender	H5b
	is not		Care level 1	H2b
		is not	Perceived health status	H4b

expected reliability influences trust. Reliability and the impact of perfect vs. imperfect automation can be found in other multiple areas as an influencing factor for trust as well[35,92,97].

Interest in technology and information procurement are further variables with a positive influence on AAL intention usage. People who are interested in new technologies have a higher intention to use AAL. Information procurement as an influencing factor is also positively correlated with intention to use. Thus, H9a and H9b can be verified.

Conclusion

Summarizing, the present study revealed perceived ease of use, perceived usefulness, and expected reliability as determinants for older people's trust in AAL technology. Furthermore, trust as well as interest in technology and information procurement influenced the intention to use AAL. Counter to the idea of developers of AAL products, people without a care level, who do not need support by public or private organizations, showed higher values for trust and intention to use. In contrast, the sub-sample comprising CL1 people of a higher age on average showed lower values.

In total, AAL technology is not well known in society today. Based on the results of the present study, some implications for marketing of AAL and the health care market can be derived. Reliability of AAL is an extremely important factor to generate trust. Moreover, perceived ease of use, for example, was increased by tablets, which are simple to handle, or well-written manuals, and perceived usefulness by enhancement of older people's involvement could lead to higher trust in AAL.

Trust as an influencing factor with the highest explanatory value for intention to use should be moved into focus. These results should be taken into consideration during development of AAL products; not only at the moment at which the advertising campaigns start, but much more earlier, the requirements of the target group must be taken into account. Regardless of gender, marketing activities for AAL should inform relatives and children, since information procurement also influences intention to use. Target group-specific information management can increase the social relevance of AAL. Within the health care market, assistive technology which supports human care givers is already growing in importance. Focusing on the trust factor in AAL could help to achieve a better reputation. Currently, there is no established market for AAL technology in Germany. Assuming that in future Germany's population is ageing furthermore and will also have a greater affinity for technology, it can be recommended to reinforce and expand the AAL market. However, beside economic and technical aspects, the special needs and requirements of each user group should be considered to ensure a successful implementation of AAL. The success of AAL is strongly dependent on whether user barriers are taken into account.

Limitations

Although the first part of the questionnaire introduced the AAL technology as well as the terms 'smartphone' and 'sensor', some respondents have indicated that they were not able to imagine how the technology works. This was not only due to the fact that the operation of the technology was not understandable, but might also be due to general attitudes of older people. This leads to the question on which knowledge base some of the participants have answered the questionnaire.

Furthermore, it is relevant to note that the used survey instrument was extensive with eleven pages. Therefore, the question arises as to what extent the accuracy of the item response was negatively affected by the time required. Some responses might also be arbitrary. Additionally, high numbers of missing values (n=77 to n=93) in the scale 'expected reliability' were found. These findings may indicate that the items were difficult to understand or due to a lack of understanding concerning the new technology not being sufficient to assess by the questionnaire.

However, a negative attitude toward the support technology has been observed in some participants. Especially, the planned use of sensors to support (health) risk situations met with strong reservations of some people. This follows on to the fact that external factors and personality traits are further determinants which influence the responses. Due to the participants' age and the length of the already existing questionnaire, no further variables could be explored.

Further research

As seen in the previously performed literature review, the key finding was that the examination of trust in context of AAL technology needs to intensify[55]. This paper deals with 292 participants over 50 years old and, therefore, a large sample compared to previous studies. By using a scenario-based approach for measuring trust in AAL, a broadened spectrum of the technology was considered. The described scenarios 'A fall' and 'The stove' are analyzed as the most critical issues for elderly people dealing with AAL.

In a next step, we plan to transfer the knowledge from the survey to an experimental setting. On

the one hand, this setting should be inspired by the results of the survey; on the other hand, a non-hazardous scenario must be chosen. Moreover, in a real-life emergency situation, an impaired person has to trust the system in absence of suitable alternatives. According to these deliberations, the following two experiments will consider situations in which participants have to handle AAL by an application on a tablet computer. The first experiment differentiates between personal remote assistance by voice over IP support and an embedded technical assistance. The second experiment examines the variation of reliability in AAL technology. In order to establish reliable information concerning the relationship of trust, use intention and actual usage, a long-term study would be needed. For this study, AAL actuators and sensors should be integrated into the home of participants and actual use should be controlled over a period of several months.

Acknowledgement
The research was supported by grants from the German Federal Ministry of Education and Research (BMBF) as part of the project SMILEY (Smart and Independent Living for the Elderly) supported by BMBF under contract 01FC10004.

References

1. United Nations Department of Economic and Social Affairs (UNDESA). Population Ageing and Development 2009. New York: United Nations; 2009; www.un.org/esa/population/publications/ageing/ageing2009chart.pdf; retrieved November 11, 2013
2. Statistisches Bundesamt. Alter im Wandel. Ältere Menschen in Deutschland und der EU [Seniority at change. Elderly people in Germany and the EU]. Wiesbaden: Statistisches Bundesamt; 2012; www.destatis.de/DE/Publikationen/Thematisch/Bevoelkerung/Bevoelkerungsstand/AlterimWandel0010017129004.pdf?__blob=publicationFile; retrieved November 11, 2013
3. Institut für Sozialforschung und Sozialwirtschaft e.V. Ausgewählte Demografieprojekte aus den Forschungs- und Entwicklungsprogrammen des Bundesministeriums für Bildung und Forschung, Innovationen mit Dienstleistungen und Arbeiten – Lernen – Kompetenzen entwickeln Innovationsfähigkeit in einer modernen Arbeitswelt [Selected demographic projects from research and developement programs of the Federal Ministry of Education and Research, innovation by services and work – learn – develop competencies, innovation ability in a modern working environment]. In: 5. Demografie-Kongress: Der Staat im Wandel Generationenpolitik zwischen Fürsorge, Vorsorge und Gewährleistung. Berlin; 2010
4. Compagna D, Derpman S, Helbig T, Shire K. Pflegenotstand technisch lösbar? Funktional-partizipative Technikentwicklung im Pflegesektor [Shortage of nurses solvable by technology? Functional-participatory technology developement at the nursing sector]. Technik-Folgenabschätzung – Theorie und Praxis 2011;20(1):71-75
5. Bundesministerium für Bildung und Forschung BMBF . AAL, Altersgerechte Assistenzsysteme für ein gesundes und unabhängiges Leben [Ambient assisted living systems for a healty and independent life]. Berlin: BMBF; 2010; www.aal-deutschland.de/deutschland/aal-faltblatt; retrieved July 1, 2013
6. Broek G van den. The need for interoperability and standards in AAL. In: Proceedings of the AAL FORUM 09 Vienna - Innovative ICT Solutions for Older Persons – A New Understanding. Vienna; 2010; pp 150-155
7. Elder-Spaces. Managing Older People Social Relationships for better Communication, Activation and Interaction. Athens: Elder Spaces; 2011; www.elderspaces.eu; retrieved October 28, 2013
8. FoSIBLE. Fostering Social Interaction for a Better Life of the Elderly. Duisburg: FoSIBLE Project Coordination; 2013; http://fosible.eu/; retrieved October 28, 2013
9. Mylife. Multimedia technology to support independence for and participation by people with dementia. Oslo: Karde; 2012; www.karde.no/MYLIFE_english.html; retrieved October 28, 2013
10. ALADDIN. Supporting the self-management of dementia at home. Athens: ICCS; 2013; www.aladdin-project.eu/; retrieved October 28, 2013
11. Belbachir AN, Litzenberger M, Schraml S, Hofstatter M, Bauer D, Schon P, Humenberger M, Sulzbachner C, Lunden T, Merne M. CARE: A dynamic stereo vision sensor system for fall detection. In: IEEE International Symposium - Circuits and Systems (ISCAS). Seoul; 2012; pp 731-734; doi:10.1109/ISCAS.2012.6272141
12. Georgieff P. Ambient Assisted Living, Marktpotenziale IT-unterstützter Pflege für ein selbstbestimmtes Altern [Market potential of IT-supported care for self-determined aging]. FAZIT-Schriftenreihe. Stuttgart: MFG Stiftung Baden-Württemberg; 2008
13. Fraunhofer-Institut für Software- und Systemtechnik ISST.Smart and Independent Living for the Elderly - SMILEY. Projektabschlussbericht [Final project report]. Dortmund: Fraunhofer ISST; 2013; www.isst.fraunhofer.de/content/dam/isst/de/documents/Forschungsnews/Fraunhofer-ISST_SMILEY-Schlussbericht_1.1.pdf; retrieved January 3, 2014
14. Bundesministerium des Innern. Demografiebericht - Bericht der Bundesregierung zur demografischen Lage und künftigen Entwicklung des Landes [Demographic report – Report of the Federal Government about the demographic situation and the future developement of the country]. Berlin: Niestetal; 2011
15. Statistisches Bundesamt: Bevölkerung Deutschlands bis 2060 - 12. Koordinierte Bevölkerungsvorausberechnung [Population of Germany until 2060 – 12th coordinated population forecast]. Wiesbaden: Statistisches

Bundesamt; 2009; https://www.destatis.de/DE/Publikationen/Thematisch/Bevoelkerung/VorausberechnungBevoelkerung/BevoelkerungDeutschland2060Presse5124204099004.pdf?__blob=publicationFile; retrieved July 1, 2013
16. Schmid A, Dörfler I, Dany F. CrossGeneration – Einsatzmöglichkeiten von IT-Systemen als Antwort auf zukünftige Herausforderungen des Gesundheitssystems [CrossGeneration – Application possibilities of IT systems as an answer to future challenges of the healthcare system]. In: 4. Deutscher AAL-Kongress, Demografischer Wandel –Assistenzsysteme aus der Forschung in den Markt. Berlin; 2011
17. Statistische Ämter des Bundes und der Länder. Demografischer Wandel in Deutschland, Heft 2, Auswirkungen auf Krankenhausbehandlungen und Pflegebedürftige im Bund und in den Ländern [Demographic change in Germany, Issue 2, Consequences on hospital treatments and care recipients on the Federal Republic and the Federal States]. Wiesbaden: Statistische Ämter des Bundes und der Länder; 2010; www.statistikportal.de/statistikportal/demografischer_wandel_heft2.pdf; retrieved July 1, 2013
18. Bundesministerium für Gesundheit BMG. Pflegebedürftigkeit [Care dependency]. Bonn: BMG; 2013; www.bmg.bund.de/pflege/pflegebeduerftigkeit/pflegebeduerftigkeit.html; retrieved November 11, 2013
19. Bundesministerium für Gesundheit (BMG). Pflegestufen [Level of Care]. Bonn: BMG; 2013; www.bmg.bund.de/pflege/pflegebeduerftigkeit/pflegestufen.html; retrieved November, 11 2013
20. Backes GM, Clemens W. Lebensphase Alter, Eine Einführung in die sozialwissenschaftliche Alternsforschung [Seniority as a phase of life, An introduction into social-scientific research into aging]. Weinheim: Beltz Juventa; 2008
21. Paris C. Analysis of the future need and demand for appropriate models of accommodation and associated services for older people. The future housing and support needs of older people in Northern Ireland. Ulster: C.Paris; 2010; www.nihe.gov.uk/analysis_of_the_future_need_and_demand_for_appropriate_models_of_accommodation_and_associated_services_for_older_people__published_february_2011_.pdf; retrieved July 1, 2013
22. Bridge C, Davy L, Judd B, Flatau P, Morris A, Phibbs P. Age-specific housing and care for low to moderate income older people - AHURI Final Report No. 174. Melbourne: Australian Housing and Urban Research Institute; 2011; www.be.unsw.edu.au/sites/default/files/upload/research/centres/cf/publications/ahuriprojectreports/AHURI_Final_Report_No174.pdf; retrieved July 1, 2013
23. Bundesministerium für Familie, Senioren, Frauen und Jugend. Fünfter Bericht zur Lage der älteren Generation in der Bundesrepublik Deutschland, Potenziale des Alters in Wirtschaft und Gesellschaft, Der Beitrag älterer Menschen zum Zusammenhalt der Generationen - Bericht der Sachverständigenkommission [5th report about the state of the elderly at the federal republic of Germany; potential of elderly citizens at economy and society; the contribution of elderly citizens to the solidary between the generations – specialist report]. Berlin: BMFSFJ; 2005; www.bmfsfj.de/RedaktionBMFSFJ/Abteilung3/Pdf-Anlagen/fuenfter-altenbericht,property=pdf,bereich=,rwb=true.pdf; retrieved July 1, 2013
24. European Ambient Assisted Living Innovation Alliance (AALIANCE). Ambient Assisted Living Roadmap. Amsterdam: IOS Press; 2010
25. Giesecke S, Hull J, Schmidt S, Strese H, Weiß C, Baumgarten D. Ambient Assisted Living. Country Report Germany: White Paper. Berlin; 2005
26. Becks T, Dehm J, Eberhardt B. Ambient Assisted Living. Neue "intelligente" Assistenzsysteme für Prävention, Homecare und Pflege [Ambient Assisted Living. New intelligent assistance systems for prevention, homecare and care]. Frankfurt am Main: Deutsche Gesellschaft für Biomedizinische Technik; 2007
27. Gersch M, Lindert R, Hewing M. AAL- Business models: Different prospects for the successful implementation of innovative services in the primary and secondary healthcare market. In: Proceedings of the AALIANCE European Conference on AAL. Malaga; 2010
28. BMBF/VDE Innovationspartnerschaft AAL. Ambient Assisted Living – ein Markt der Zukunft, Potenziale, Szenarien, Geschäftsmodelle [Ambient Assisted Living – A future market, potentials, scenarios, business models]. Berlin: VDE; 2012
29. Moser-Siegmeth V, Aumayr G. Alter und Technik, Theorie und Praxis [Old age and technology, theory and practice]. Wien: Facultas; 2011
30. Heinze R, Ley C. Abschlussbericht des Forschungsprojekts Vernetztes Wohnen: Ausbreitung, Akzeptanz und nachhaltige Geschäftsmodelle [Final report of the research project cross-linked living: expansion, acceptance and sustainable business models]. Bochum: InWIS; 2009; www.sowi.rub.de/mam/content/heinze/heinze/abschlussbericht_vernetzteswohnen.pdf; retrieved July 1, 2013
31. Ambient Assisted Living Joint Programme. Definition of end-users in the AAL Joint Programme. Brussels: AAL ASSOCIATION; 2010; www.aal-europe.eu/get-involved/i-am-a-user-2/; retrieved July 1, 2013
32. Institut für Sozialforschung und Sozialwirtschaft e.V. Ergebnisse des BMBF-Förderschwerpunktes: Technologie und Dienstleistungen im demografischen Wandel [Results of the BMBF-funding focus: technology and services in the course of demographic change]. Saarbrücken: Institut für Sozialforschung und Sozialwirtschaft; 2011
33. Luhmann N. Trust and Power. New York: Wiley; 1979
34. Xin L, Hess TJ, Valacich JS. Why do we trust new technology? A study of initial trust formation with organizational information systems. Journal of Strategic Information Systems 2008;17(1):39-71

35. Lee JD, See KA. Trust in automation: Designing for appropriate reliance. Human Factors 2004;46(1):50-80; doi:10.1518/hfes.46.1.50.30392
36. Muir BM. Trust between humans and machines, and the design of decision aids. International Journal of Man Machine Studies 1987;27(5-6):527–539; doi:10.1016/S0020-7373(87)80013-5
37. Lee J, Moray N. Trust, control strategies and allocation of function in human-machine systems. Ergonomics 1992;35(10):1243–1270; doi:10.1080/00140139208967392
38. Lee JD, Moray N. Trust, self- confidence, and operators' adaptation to automation. International Journal of Human-Computer Studies 1994;40(1):153–184; doi:10.1006/ijhc.1994.1007
39. Merritt SM, Ilgen DR. Not all trust is created equal: dispositional and history-based trust in human automation interactions. Human Factors 2008;50(2):194-210; doi:10.1518/001872008X288574
40. Parasuraman R, Riley V. Humans and automation: use, misuse, disuse, abuse. Human Factors 1997;39(2):230–253; doi:10.1518/001872097778543886
41. Dzindolet MT, Pierce LG, Beck HP, Dawe LA. The perceived utility of human and automated aids in a visual detection task. Human Factors 2002;44(1):79–94; doi:10.1518/0018720024494856
42. Abe G, Richardson J. Alarm timing, trust and driver expectation for forward collision warning systems. Applied Ergonomics 2006;37(5):577-586, doi:10.1016/j.apergo.2005.11.001
43. Chugh JS, Caird JK. In-Vehicle Train Warnings (ITW): The Effect of Reliability and Failure Type on Driver Perception Response Time and Trust. In: Human Factors and Ergonomics Society - 43rd Annual Meeting. Houston; 1999, pp 1012-1016; doi:10.1177/154193129904301803
44. Lees MN, Lee JD. The influence of distraction and driving context on driver response to imperfect collision warning systems. Ergonomics 2007;50(8):1264–1286; ; doi:doi:10.1080/00140130701318749
45. Parasuraman R, Miller C. Trust and etiquette in high criticality automated systems. Communications of the Association for Computing Machinery 2004;47(4):51–55; doi:10.1145/975817.975844
46. Hughes JS, Rice S, Trafimow D, Clayton KD. The automated cockpit: A comparison of attitudes towards human and automated pilots. Transportation Research 2009;F12(5):428-439; doi:10.1016/j.trf.2009.08.004
47. Wickens CD, Rice S, Keller D, Hutchins S, Hughes J, Clayton K. False alerts in air traffic control conflict alerting system: Is there a "cry wolf" effect?. Human Factors 2009;51(4):446-462; doi:10.1177/0018720809344720
48. Rice S. Examining single- and multiple-process theories of trust in automation. The Journal of general psychology 2009;136(3):303-319; doi:10.3200/GENP.136.3.303-322
49. Rice S, Clayton KD, Wells A, Keller D. Manipulating Trust Behaviors in a Combat Identification Task. Workshop Human Factors Issues in Combat Identification, 2008
50. Wang L, Jamieson GA, Hollands JG. Trust and Reliance on an Automated Combat Identification System. Human Factors 2009;51(3):281-290; doi:10.1177/0018720809338842
51. Wiegmann DA, Rich A, Zhang H. Automated diagnostic aids: The effects of aid reliability on users' trust and reliance. Theoretical Issues in Ergonomics Science 2001;2(4):352-367; doi:10.1080/14639220110110306
52. Bainbridge WA, Hart J, Kim ES, Scassellati B. The effect of presence on human-robot interaction. In: Proceedings of the 17th IEEE Symposium on Robot and Human Interactive Community (pp. 701–706). Munich; 2008; pp 701-706; doi:10.1109/ROMAN.2008.4600749
53. Freedy A, Visser E de, Weltman G, Coeyman N. Measurement of trust in human-robot collaboration. In: Proceedings of the 2007 International Conference on Collaborative Technologies and Systems. Orlando; 2007; pp 106-114; doi:10.1109/CTS.2007.4621745
54. Shinozawa K, Reeves B, Wise K, Lim S, Maldonado H, Naya F. Robots as new media: a cross-cultural examination of social and cognitive responses to robotic and on-screen agents, Proceedings of the 53rd annual conference of the international communication association, information systems division. San Diego; 2003; pp 998–1002
55. Steinke F, Fritsch T, Silbermann L. Trust in Ambient Assisted Living (AAL) - A Systematic Review of Trust in Automation and Assistance Systems. International Journal On Advances in Life Sciences 2012;4(3-4):77-88
56. Grefen D, Karahanna E, Straub DW. Trust and TAM in Online Shopping: An Integrated Model. MIS Quarterly 2003;27(1):51-90
57. Steinke F, Fritsch T, Brem D, Simonsen S. Requirement of AAL systems – Older persons' trust in sensors and characteristics of AAL technologies. In: Proceedings of the 5th ACM International Conference on Pervasive Technologies Related to Assistive Environments. Heraklion; 2012; pp 1-6; doi:10.1145/2413097.2413116
58. Davis FD. A technology acceptance model for empirically testing new end-user information systems: Theory and results. Unpublished doctoral dissertation. Cambridge: Massachusetts Institute of Technology; 1986
59. Davis FD. User acceptance of information technology: system characteristics, user perceptions and behavioural impacts. International Journal of Man-Machine Studies 1993;38(3):475-487; doi:10.1006/imms.1993.1022
60. Fishbein M, Ajzen I. Attitude, Intention and Behavior: An Introduction to Theory and Research. Reading: Addison-Wesley; 1975
61. Davis F.D. Perceived usefulness, perceived ease of use, and user acceptance of information technology. MIS Quarterly 1989;13(3):319–340; doi:10.2307/249008

62. Davis FD, Bagozzi RP, Warshaw PR. User Acceptance of Computer Technology. A Comparison of Two Theoretical Models. Management Science 1989;35(8):982-1003; doi:10.1287/mnsc.35.8.982
63. Turner M, Kitchenham B, Brereton P, Charters S, Budgen D. Does the technology acceptance model predict actual use? A systematic literature review. Information and Software Technology 2010;52(5):463–479; doi:10.1016/j.infsof.2009.11.005
64. Legris P, Ingham J, Collerette P. Why do people use information technology? A critical review of the technology acceptance model. Information & Management 2003;40(3):191-204; doi:10.1016/S0378-7206(01)00143-4
65. Venkatesh V, Davis FD. A Theoretical Extension of the Technology Acceptance Model: Four Longitudinal Field Studies. Management Science 2000;46(2):86-204; doi:10.1287/mnsc.46.2.186.11926
66. Venkatesh V, Bala H. Technology Acceptance Model 3 and a Research Agenda on Interventions. Decision Sciences 2008;39(2):273-315; doi:10.1111/j.1540-5915.2008.00192.x
67. King WR, He J. A meta-analysis of the technology acceptance model. Information & Management 2006;43(6):740–755; doi:10.1016/j.im.2006.05.003
68. Hu PJ, Chau PYK, Liu SOR, Yan TK. Examining the Technology Acceptance Model Using Physican Acceptance of Telemedicine Technology. Journal of Management Information Systems 2012;16(2):91-112
69. Pavlou P. A. Consumer acceptance of electronic commerce: Integrating trust and risk with the technology acceptance model. International Journal of Electronic Commerce 2003;7(3):69–103
70. Venkatesh V, Morris MG, Davis GD, Davis FB. User Acceptance of Information Technology: Toward a Unified View. MIS Quarterly 2003;27(3):425-478
71. Heerink M, Kröse B, Evers V, Wielinga B. Assessing Acceptance of Assistive Social Agent Technology by Older Adults: the Almere Model. International Journal of Social Robotics 2012;2(4):361–375; doi:10.1007/s12369-010-0068-5
72. World Health Organization (WHO). Health statistics and health information systems: Definition of an older or elderly person. Geneva: WHO; 2011; http://www.who.int/healthinfo/survey/ageingdefnolder/en/index.html; retrieved October 28, 2012
73. Baltes PB. On the incomplete architecture of human ontogeny: Selection, optimization, and compensation as foundation of developmental theory. American Psychologist 1997;52(4):366–380; doi:10.1037//0003-066X.52.4.366
74. Baltes MM. The psychology of the oldest-old: The fourth age. Current Opinion Psychiatry 1998;11(4):411–415; doi:10.1097/00001504-199807000-00009
75. Baltes PB, Smith J. Multilevel and systemic analyses of old age: Theoretical and empirical evidence for a fourth age. In: Bengtson VL, Schaie KW, editors. Handbook of Theories of Aging. New York: Springer; 1999; pp 153–173
76. Baltes PB, Smith J. New Frontiers in the Future of Aging: From Successful Aging of the Young Old to the Dilemmas of the Fourth Age. Gerontology 2003;49(2):123–135; doi:10.1159/000067946
77. Ferraro KF. Self-Ratings of Health among the Old and the Old-Old. Journal of Health and Social Behavior 1980;21(4):377-383; doi:10.2307/2136414
78. Field D, Minkler M. Continuity and Change in Social Support Between Young-old and Old-old or Very-old Age. Journal of Gerontology 1988;43(4):100-106; doi:10.1093/geronj/43.4.P100
79. Neugarten BL. Age Groups in American Society and the Rise of the Young-Old. The Annals of the American Academy of Politica and Social Science 1974;415(1):187-198; doi:10.1177/000271627441500114
80. Suzman RM, Willis DP, Manton KG. The oldest old. New York: Oxford University Press; 1992; doi:10.2307/3349879
81. Robinson RV, Jackson EV. Is Trust in Others Declining in America? An Age–Period–Cohort Analysis. Social Science Research 2001;30(1):117-145; doi:10.1006/ssre.2000.0692
82. Fox JE, Boehm-Davis DA. Effects of age and congestion information accuracy of advanced traveler information systems on user trust and compliance. Transportation Research Record 1998;1621:43–49; doi:10.3141/1621-06
83. Ho G, Wheatley D, Scialfa CT. Age differences in trust and reliance of a medication management system. Interacting with Computers 2005;17(6):690-710; doi:10.1016/j.intcom.2005.09.007
84. Lee JD, Gore BF, Campbell JL. Display alternatives for in-vehicle warning and sign information: Message style, location, and modality. Transportation Human Factors 1999;1(4):347–377; doi:10.1207/sthf0104_6
85. Sanchez J, Fisk AD, Rogers WA. Reliability and age-related effects on trust and reliance of a decision support aid. In: Proceedings of the Human Factors and Ergonomics Society 38th Annual Meeting. Santa Monica; 2004; doi:10.1177/154193120404800366
86. World Health Organization (WHO). Uses of Epidemiology in Aging. Technical Report Series 706. Geneva: WHO; 1984
87. Statistisches Bundesamt. Alleinlebende in Deutschland – Ergebnisse des Mikrozensus 2011 [People living alone in Germany – Results of the micro-census 2011]. Wiesbaden: Statistisches Bundesamt; 2012; https://www.destatis.de/DE/PresseService/Presse/Pressekonferenzen/2012/Alleinlebende/begleitmaterial_PDF.pdf;jsessionid=96F9638AF6F1DFDF9F318943D7CA39AF.cae3?__blob=publicationFile; retrieved October 28, 2013
88. Chen Y, Sun Y. Age differences in financial decision-making: Using simple heuristics. Educational Gerontology 2003;29(7):627–635; doi:10.1080/713844418

89. Ho G, Kiff LM, Plocher T, Haigh KZ. A model of trust and reliance of automation technology for older users. In: Papers of the AAAI Fall Symposium 'CaringMachines: AI in Eldercare'. Menlo Park; 2005; pp 45-50
90. Montague ENH, Winchester III WW, Kleiner BM. Trust in medical technology by patients and healthcare providers in obstetric work systems. Behaviour & Information Technology 2010;29(5):541-554; doi:10.1080/01449291003752914
91. McGuirl JM, Sarter NB. Supporting trust calibration and the effective use of decision aids by presenting dynamic system confidence information. Human Factors 2006;48(4):656-665; doi:10.1518/001872006779166334
92. Neyedli HF, Wang L, Jamieson GA, Hollands JG. Evaluating Reliance on Combat Identification Systems: The Role of Reliability Feedback. In: Andrews DH, Herz RP, Wolf MB, editors. Human factors Issues in Combat Identification. Burlington: Ashgate; 2010; pp 249-264
93. Pohlmeyer AE. Identifying Attribute Importance in Early Product Development. Exemplified by Interactive Technologies and Age. Doctoral dissertation. Technische Universität Berlin; 2012
94. Keller A, Rice S. System-Wide versus Component-Specific Trust Using Multiple Aids. The Journal of General Psychology 2010;137(1):114–128
95. Madhavan P, Wiegmann DA, Lacson FC. Automation failures on tasks easily performed by operators undermine trust in automated aids. Human Factors 2006;48(2):241-256; doi:10.1518/001872006777724408
96. Coughlin JF, Lau J, Ambrosio L, Reimer B. Adult children's perceptions of intelligent home systems in the care of elderly parents. In: Proceedings of the 3rd International Convention on Rehabilitation Engineering & Assistive Technology. New York; 2009; p 12; doi:10.1145/1592700.1592714
97. Dixon SR, Wickens CD. Automation reliability in unmanned aerial vehicle control: A reliance-compliance model of automation dependence in high workload. Human Factors 2006;48(3):474-486; doi:10.1518/001872006778606822
98. Jasemian Y. Elderly comfort and compliance to modern telemedicine system at home - Pervasive Computing Technologies for Healthcare. In: 2nd International Conference on Pervasive Health. Tampere; 2008; pp 60-63; doi:10.1109/PCTHEALTH.2008.4571027
99. Miller CA, Haigh K, Dewing W. First, cause no harm: Issues in building safe, reliable and trustworthy elder care systems. In: Proceedings of the AAAI-02 Workshop Automation as Caregiver. Edmonton; 2002; pp 80-84
100. Rovira E, McGarry K, Parasuraman R. Effects of imperfect automation on decision making in a simulated command and control task. Human Factors 2007;49(1):76–87; doi:10.1518/001872007779598082
101. Spain RD, Bliss JP. The effect of sonification display pulse rate and reliability on operator trust and perceived workload during a simulated patient monitoring task. Ergonomics 2008;51(9):1320–1337; doi:10.1080/00140130802120234
102. Daley DT. Reliability assessment: a guide to aligning expectations, practices and performance. New York: Transatlantic; 2010
103. Sayago S, Blat J. Telling the story of older people e-mailing: an ethnographical study. International Journal of Human-Computer Studies 2010;68(1-2):105-120; doi:10.1016/j.ijhcs.2009.10.004
104. Grünig R, Kühn R. Successful Decision-making, A Systematic Approach to Complex Problems. Berlin: Springer; 2009
105. Carroll JM. Five reasons for scenario-based design. Interacting with computers 2000;13(1):43-60; doi:10.1016/S0953-5438(00)00023-0
106. Kaiser HF, Little RJ, Mark J. IV. Educational and Psychological Measurement 1974;34(1):111-117
107. Jian J-Y, Bisanz AM, Drury CG. Foundations for an Empirically Determined Scale of Trust in Automated Systems. International Journal of Cognitive Ergonomics 2000;4(1):53-71; doi:10.1207/S15327566IJCE0401_04
108. Kornmeier K. Determinanten der Endkundenakzeptanz mobilkommunikationsbasierter Zahlungssysteme - Eine theoretische und empirische Analyse [Determinants of end customer acceptance regarding mobile communication based payment systems – A theoretical and empirical analysis]: Doctoral dissertation, University Duisburg-Essen; 2009
109. Montague E. Validation of a trust in medical technology instrument. Applied Ergonomics 2010;41(6):812-821; doi: 10.1016/j.apergo.2010.01.009
110. Karrer K, Glaser C, Clemens C, Bruder C. Technikaffinität erfassen – der Fragebogen TA-EG [Capture affinity for technology – the TA-EG questionnaire]. Der Mensch als Mittelpunkt technischer Systeme 2009;Part 8; pp196-201
111. Pütz C. Wirkungen von electronic-Word-of-Mouth-Empfehlungen bei misstrauischen Rezipienten: Eine empirische Untersuchung unter Betrachtung der Empfehlungskongruenz sowie der Botschaftsargumentation [Impact of electronic word-of.mouth recommendations on distrustful recipients: An empirical study taking into account congruence of recommendation and argumentation of messages]. Doctoral dissertation. Rheinisch-Westfälische Technische Hochschule Aachen; 2009
112. Bullinger M, Kirchberger I, Ware J. Der deutsche SF-36 Health Survey Übersetzung und psychometrische Testung eines krankheitsübergreifenden Instruments zur Erfassung der gesundheitsbezogenen Lebensqualität [The German SF-36 Health Survey – Translation and psychometric testing of an across-disease instrument for the detection of health-related quality of life]. Zeitschrift für Gesundheitswissenschaften 1995;03(1):21-36

Appendix 1. Questionnaire used in this study (in German) with a translation into English

#		Questions used	Translation
1		Mit diesen Fragen möchte ich herausfinden, wie Sie die Benutzerfreundlichkeit der Unterstützungstechnik anhand der Geschichte einschätzen würden.	With these questions, I want to find out how you estimate the ease of use of the assistive technology based on the present story.
	a	Ich denke, es würde mich verwirren die Unterstützungstechnik zu verwenden.	I think it would confuse me to use the assistive technology.
	b	Ich denke, ich würde häufig Fehler bei der Anwendung der Unterstützungstechnik machen.	I think I would often make errors when using the assistive technology.
	c	Ich denke, der Umgang mit der Unterstützungstechnik würde mich frustrieren.	I think the handling of the assistive technology is frustrating.
	d	Ich denke, ich würde bei der Nutzung der Unterstützungstechnik häufig das Handbuch benötigen	I think I would often need the manual when using the assistive technology.
	e	Ich denke, der Umgang mit der Unterstützungstechnik erfordert eine Menge meiner geistigen Anstrengung.	I think interacting with the assistive technology requires a lot of my mental effort.
	f	Ich denke, ich würde es umständlich finden, die Unterstützungstechnik zu verwenden.	I think I would find it cumbersome to use the assistive technology.
	g	Insgesamt denke ich, würde die Unterstützungstechnik einfach zu bedienen sein.	Overall, I think that the assistive technology would be easy to use.
2		Mit diesen Fragen möchte ich herausfinden, wie Sie die Nützlichkeit der Unterstützungstechnik anhand der Geschichte bewerten würden.	With these questions, I want to find out how you estimate the usefulness of the assistive technology based on the present story.
	a	Die Unterstützungstechnik verbessert die Qualität des Wohnens im eigenen Haushalt.	The assistive technology improves the quality of living in your own household.
	b	Ich würde es als komfortabel empfinden, von der Unterstützungstechnik im häuslichen Umfeld unterstützt zu werden.	I would find it convenient to be supported by the assistive technology in my home environment.
	c	Die Unterstützungstechnik unterstützt das Leben in meinem eigenen Haushalt.	The assistive technology supports living in my own household.
	d	Die Unterstützungstechnik ermöglicht mir, länger in meinem eigenen Haushalt zu leben, als dies sonst möglich wäre.	The assistive technology allows me to live longer in my own household than I would otherwise be able to.
	e	Der Besitz der Unterstützungstechnik erhöht mein Ansehen in meinem Umfeld.	The possession of the assistive technology increases my reputation in my environment.
	f	Die Unterstützungstechnik macht es mir einfacher, länger in meinem eigenen Haushalt zu leben.	The assistive technology makes it easier to extend living in my own household.
	g	Insgesamt würde ich die Unterstützungstechnik in meinem eigenen Haushalt sinnvoll finden.	Overall, I would consider having the assistive technology in my own household as useful.
3		Die folgenden Fragen zielen darauf ab herauszufinden, wie Sie die Zuverlässigkeit der Unterstützungstechnik anhand der Geschichte einschätzen würden	The following questions aim to find out how you would estimate the reliability of the assistive technology based on the present story.
	a	Die Unterstützungstechnik erscheint mir zuverlässig.	The assistive technology appears to be reliable.
	b	Die Unterstützungstechnik erscheint mir präzise.	The assistive technology appears to be precise.
	c	Die Unterstützungstechnik erscheint mir sicher.	The assistive technology appears to be safe.
	d	Die Unterstützungstechnik erscheint mir ehrlich.	The assistive technology appears to be honest.
	e	Ich denke, die Unterstützungstechnik wird fehlerfrei arbeiten.	I think the assistive technology will work correctly.
	f	Die Unterstützungstechnik weist für mich Zuverlässigkeit auf.	The assistive technology shows reliability for me.

Appendix 1 (continued)

#	Questions used	Translation
4	Mit diesen Fragen möchte ich herausfinden, wie Sie ihr Vertrauen in die Unterstützungstechnik anhand der Geschichte einschätzen würden.	With these questions, I want to find out how you estimate your trust into the assistive technology based on the present story.
	a Die Unterstützungstechnik würde mir trügerisch erscheinen.	The assistive technology would appear deceptive to me.
	b Ich würde darauf vertrauen, dass mir die Unterstützungstechnik Sicherheit bietet.	I would trust that the assistive technology provides security to me.
	c Ich würde gegenüber der Unterstützungstechnik misstrauisch sein.	I would be wary of the assistive technology.
	d Ich würde der Unterstützungstechnik vertrauen.	I would rely in the assistive technology.
	e Ich misstraue den Absichten, Handlungen oder Folgen der Unterstützungstechnik.	I am suspicious of the intentions, actions or consequences of the assistive technology.
	f Die Aktivitäten der Unterstützungstechnik werden eine schädliche oder schädigende Folge haben.	The activities of the assistive technology will have a harmful or injurious outcome.
	g Ich vertraue auf die Unterstützungstechnik.	I trust in the assistive technology.
5	Mit diesen Fragen möchte ich herausfinden, wie stark Ihre Absichten sein würden, die vorgestellte Unterstützungstechnik zu nutzen.	With these questions, I want to find out how strong your intentions to use the presented assistive technology would be.
	a Es ist wahrscheinlich, dass ich die Technologie verwenden würde.	It is probably that I would use the technology.
	b Ich würde auf jeden Fall einmal ausprobieren, die Technologie zu nutzen.	I would at least try to use the technology.
	c Sobald die Möglichkeit besteht, würde ich die Technologie nutzen.	As soon as the opportunity arises, I would use the technology.
6	Mit diesen Fragen möchte ich ermitteln, wie Sie Ihr Interesse an technischen Geräten einschätzen würden.	With these questions, I want to determine how you would evaluate your interest in technical devices.
	a Ich informiere mich über elektronische Geräte, auch wenn ich keine Kaufabsicht habe.	I inform myself about electronic devices even if I do not have any buying intention.
	b Ich liebe es, neue elektronische Geräte zu besitzen.	I love to have new electronic devices.
	c Ich bin begeistert, wenn ein neues elektronisches Gerät auf den Markt kommt.	I am excited when a new electronic device enters the market.
	d Ich gehe gern in den Fachhandel für elektronische Geräte.	I like to go to dealers specializing in electronic devices.
	e Es macht mir Spaß, ein elektronisches Gerät auszuprobieren.	I have fun trying an electronic device.
7	Diese Fragen zielen darauf ab herauszufinden, wie Sie sich Informationen über ein elektronisches Gerät beschaffen würden.	These questions aim to find out how you would obtain information about an electronic device.
	a Ich höre auf den Rat von Freunden und Bekannten, um das beste elektronische Gerät zu finden.	I heed the advice of friends and acquaintances to find the best electronic device.
	b Ich kaufe generell nur Produkte, die meine Freunde oder Bekannten auch kaufen.	I generally buy only products that my friends or acquaintances buy
	c Ich informiere mich über ein elektronisches Gerät bei Freunden oder Familienmitgliedern, bevor ich es kaufe.	I ask friends and relatives to inform myself about an electronic device before I buy it.
	d Wenn ich nur wenig Erfahrung mit einem Produkt habe, befrage ich meine Freunde über dieses Produkt.	If I am short on experience about a product, I ask my friends about this product.
	e Um Enttäuschungen mit einem Produkt zu vermeiden, orientiere mich an den Produkten, die Andere gekauft haben.	To prevent disappointment about a product, I orientate myself towards products which others bought as well.

Appendix 1 (continued)

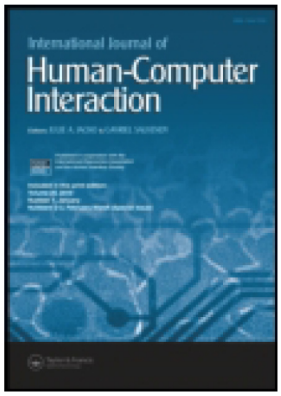
#	Questions used	Translation
8	Die folgenden Fragen zielen darauf ab, wie Sie Ihren aktuellen Gesundheitszustand einschätzen.	The following questions aim to find out how you would estimate your current health status.
	a Ich scheine etwas leichter als andere krank zu werden.	I seem to become ill little easier than others.
	b Ich bin genauso gesund wie alle anderen, die ich kenne.	I am as healthy as everyone I know.
	c Ich erwarte, dass meine Gesundheit nachlässt.	I expect that my health declines.
	d Ich erfreue mich ausgezeichneter Gesundheit.	I enjoy good health.
Welches Geschlecht haben Sie? [ ] weiblich [ ] männlich		What is your gender? [ ] female [ ] male
Wie alt sind Sie? Ich bin _____ Jahre alt.		How old are you? I am ____ years old.
Welchen Bildungsabschluss haben Sie? Bitte wählen Sie den höchsten Bildungsabschluss, den Sie bisher erreicht haben. [ ] kein offizieller Schulabschluss [ ] Haupt-/ Volkshochschulabschluss [ ] Mittlere Reife, Realschulabschluss [ ] Abitur / Fachabitur [ ] Hochschul-/ Fachhochschulabschluss [ ] Promotion		Which educational attainment do you have? Please select the highest educational attainment you achieved to date. No official educational attainment Secondary modern school/community college Middle school High-school diploma University/polytechnic degree Doctorate
In welchem Bereich haben Sie zuletzt gearbeitet? [ ] technischer Bereich [ ] kaufmännischer Bereich [ ] sozialer / pflegerischer Bereich [ ] sonstiger Bereich		In which area did you worked last? Technical Sales/Clerk Social/Nursing Other
Wohnen Sie alleine oder mit anderen Personen zusammen? [ ] alleine [ ] zusammen mit anderen Personen		Do you live alone or together with other people? Alone With other people
Wie hoch ist Ihr monatliches Nettoeinkommen ungefähr? Gemeint ist der Betrag, der sich aus allen Einkünften zusammensetzt und nach Abzug der Steuern und Sozialversicherungen übrig bleibt. _____ € netto [ ] keine Angabe		What is your monthly net income? This means the amount composed of all proceeds which remain after deduction of taxes and social insurance. _____ € net Prefer not to say
Besitzen Sie ein Smartphone? [ ] ja [ ] nein		Do you own a smart phone? Yes No
Vielen Dank für Ihre Teilnahme		Thank you for your participation

Appendix 2. Scenarios used with author translations of the original German text

A fall	**The stove**
Imagine you are alone in your house or apartment. You are sitting at the kitchen table and eating. After lunch you want to bring the dishes to the sink. You have felt uncomfortable all day long and you are not very steady on your feet. On the way to the sink, you fall and hurt your hip. You cannot get up by yourself anymore. As a result, you are no longer able to make an emergency call. Although you call out for help, no one will notice you. Fortunately, you have installed appropriate sensors in your home that detect the fall and automatically send an alert to your smartphone. Your phone recognizes the emergency situation and sets an emergency call. An emergency physician in your area has now been called. You hear that a distress call was initiated because the device will beep three times aloud. In addition, the display lights up. This process takes place without your active participation. You do not need to hold your smartphone in your hand. It is sufficient if the unit is turned on in the apartment. The informed emergency physician can now help you and save your life in an emergency.	Imagine you want to leave your apartment after lunch to go to the doctor. Accidentally, you forget to turn off the stove. You did not notice it when leaving the apartment. So there would be the risk of domestic fire. Fortunately, you have installed sensors on your stove and your front door. Once you leave the front door, the sensors detect that the oven is not turned off and send an alert to your smartphone. This process takes place without your active participation. At the front door you will be automatically reminded to turn off the stove by a very loud beep and a flashing of your smartphone. However, it is necessary to have the smartphone turned on and to carry it with you. Reminded by the smartphone, you go back to the kitchen and turn off the stove. The use of the support technology therefore ensures that no damage occurs in your home during your absence.

RESEARCH ARTICLE 3

Steinke, F., Ingenhoff, A., & Fritsch, T. (2014). Personal remote assistance in Ambient Assisted Living experimental research of elderly people trust and intention to use. *International Journal of Human Computer Interaction, 30(7),* 560-574.



International Journal of Human-Computer Interaction
Publication details, including instructions for authors and subscription information:
http://www.tandfonline.com/loi/hihc20

Personal Remote Assistance in Ambient Assisted Living—Experimental Research of Elderly People's Trust and Their Intention to Use

Frederick Steinke[a], Alexander Ingenhoff[b] & Tobias Fritsch[c]

[a] Department of Psychology, Humboldt Universität zu Berlin, Berlin, Germany

[b] Department of Marketing and Consumer Research, Technische Universität München, München, Germany

[c] Department of Behavior and Cultural Studies, Ruprecht-Karls-Universität Heidelberg, Heidelberg, Germany

Accepted author version posted online: 04 Apr 2014.Published online: 20 May 2014.

To cite this article: Frederick Steinke, Alexander Ingenhoff & Tobias Fritsch (2014) Personal Remote Assistance in Ambient Assisted Living—Experimental Research of Elderly People's Trust and Their Intention to Use, International Journal of Human-Computer Interaction, 30:7, 560-574, DOI: 10.1080/10447318.2014.903789

To link to this article: http://dx.doi.org/10.1080/10447318.2014.903789

Intl. Journal of Human–Computer Interaction, 30: 560–574, 2014

ISSN: 1044-7318 print / 1532-7590 online
DOI: 10.1080/10447318.2014.903789

Taylor & Francis
Taylor & Francis Group

Personal Remote Assistance in Ambient Assisted Living—Experimental Research of Elderly People's Trust and Their Intention to Use

Frederick Steinke[1], Alexander Ingenhoff[2], and Tobias Fritsch[3]
[1]*Department of Psychology, Humboldt Universität zu Berlin, Berlin, Germany*
[2]*Department of Marketing and Consumer Research, Technische Universität München, München, Germany*
[3]*Department of Behavior and Cultural Studies, Ruprecht-Karls-Universität Heidelberg, Heidelberg, Germany*

The objective of this article is to analyze the meaning of two different support functions regarding the use of Ambient Assisted Living (AAL). Thirty-two older persons (M age = 69.84, SD = 6.31) and a younger control group (n = 21; M age = 24.71, SD = 2.10) were examined in an experiment with three different tasks using a tablet computer. The first group operated with a mock-up that provided personal remote assistance (PRA) and the second group with one that provided embedded technical assistance (ETA). The main results show that older participants with PRA solve significantly more tasks than people with ETA. Moreover, a significant influence of perceived ease of use with PRA is revealed. Multiple regressions in the senior sample highlight a significant connection between trust in AAL technology and perceived reliability as well as perceived ease of use. No significant correlation between the type of assistance and older persons' trust, as well as an intention to use AAL, was found.

1. INTRODUCTION

During the last decade, assistance technology in the home environment has gained in importance. Smart home technologies, which provide additional living comfort, have been brought to the market (Demiris & Hensel, 2008). In particular, ambient assisted technologies in the home environment are a growing research field with several European projects implemented since 2008. All of these projects have one thing in common: to support persons with the need of care to promote a longer independent life in their homes (Ambient Assisted Living Joint Programme, 2012). The research project "Smart and Independent Living for the Elderly" (SMILEY) underlines some important possibilities for technical support in the home environment (Fraunhofer ISST, 2013). The key phrases "access to information," "security in the household," "remembering things," and "remaining active and fit" summarize important demands, which should be addressed by AAL technology. In short, AAL comprises technical support in the home environment for elderly people (Becks, Dehm, & Eberhardt, 2007). One example solution for the use of this technology would be a household equipped with sensors and actors that monitors a situation in which a person falls down. In the case of an emergency, the technology can automatically alarm relatives or an emergency physician (Chiriac & Rosales, 2012). Moreover, these in-home technologies may have an influence on communication toward the elderly and could strengthen personal relationships (Huber et al., 2013).

In contrast to the demand for independent living, elderly persons tend to be very skeptical toward supportive technologies. The older generation did not grow up with technologies like personal computers. Therefore, those people have more difficulty using computer-based technologies (Prensky, 2001; Zhou, Rau, & Salvendy, 2012). During the course of their research, they also found that elderly consumers have a lower degree of acceptance toward medical home monitoring systems than younger ones (Ziefle, Himmel, & Wolkowska, 2011). One important reason for the use of medical technology is trust (Montague, Kleiner, & Winchester, 2009), which also has to be considered when developing AAL technologies. Furthermore, the reliance on technology is influenced by the degree of trust the user feels toward technology. For instance, technology that people did not trust was more likely to be rejected (Lee & See, 2004). In literature, plenty of articles can be found that cover the topics of human's trust in automation in general—especially in the fields of aviation and the military (Neyedli, Wang, Jamieson, & Hollands, 2010)—as well as the comparison of trust between humans and trust between humans and technology (Madhavan & Wiegmann, 2007). However, the interaction of elderly people with assistance systems is rarely covered. For the case of trust in AAL technologies, very little research exists (Steinke, Fritsch, & Silbermann, 2012). Following this logic, elderly people can be expected to have a need for help when using new

Address correspondence to Frederick Steinke, Humboldt Universität zu Berlin, Rudower Chaussee 18, 12489 Berlin, Germany. E-mail: steinkef@student.hu-berlin.de

Color versions of one or more of the figures in the article can be found online at www.tandfonline.com/hihc.

technologies. This statement can be supported by findings from the requirement analysis within the research project SMILEY, which show that concern exists in a difficult handling of an AAL technology (Fraunhofer ISST, 2013). To counteract these concerns, support by technicians and experts of the provider, while setting up and using the technology, might help. To cover and investigate this required support, the present article differentiates, in an experimental setting, between two types of support functions for older people using an AAL application on a tablet PC. The first support function is "remote assistance" (U.S. Patent No. 6,973,482 B2, 2005), which enables a third person to act on the computer from a remote location if necessary. In addition, this remote assistance is extended with a Voice over IP function including a video function (through which the older end user can communicate with the service center; Torres-Padrosa, Calle, Marzo, & Rovira, 2012; Zhang & Ansari, 2010). More precisely, in the intervention group, a member of the service-provider staff appears on the tablet PC screen and supports the older person via verbal instruction or remote clicking. In the present study, the abbreviation PRA is used, as the focus lies on the personal contact and support in contrast to the second type of assistance.

The second support function is derived from embedded user assistance, which is integrated into the user interface (Aleven, McLaren, Roll, & Koedinger, 2006; Corbin, 2003; Grayling, 2002). No personal support will be given in this type of assistance. The participants have to solve the tasks on their own with the aim of embedded technical assistance (ETA). In the experiment, ETA is characterized by an integrated technical support, which is given by highlighting a button in cases where the participant is unable to choose the correct button.

A previous study revealed that a short video instructing how to use a ticket vending machine helped older adults to improve their results in contrast to a younger control group without video instruction (Sengpiel & Wandke, 2010). The present article aims to investigate whether it is useful to integrate a real-time assistance function in an AAL application. For this purpose, the study confronts participants with both of the aforementioned presented assistance types—PRA and ETA—to analyze older people's perceived ease of use, trust, and intention to use, in the context of AAL. This article addressed the following main research question: *Does a significant relationship exist between elderly people's trust and the type of assistance integrated into an AAL application?*

2. BACKGROUND

2.1. Elderly People in the Context of AAL

Western societies, and especially German society, are characterized by demographic ageing (Statistisches Bundesamt, 2011). Today, Germany already shows the highest percentage of people 65 years of age and older within the European Union (Statistisches Bundesamt, 2012). A central concern of elderly people is their living situation. Most of the elderly prefer to stay in their accustomed living environment and live independently for as long as possible (Fraunhofer ISST, 2013; Osl, Benz, & Österle, 2010). Moving into nursing establishments equals a loss of autonomy and quality of life. Furthermore, once they have moved out of the accustomed environment, the elderly perceive this step as a manifestation of weakness (Schneekloth & Wahl, 2005). Research scientists have identified these needs of elderly people and developed new technologies that help to compensate deficits due to age and disability in order to support their "active ageing" (World Health Organization, 2013). Intelligent systems can prevent elderly people from making fatal mistakes, such as medication errors, and thereby disburden professional care attendants and reduce costs (Schneekloth & Wahl, 2005). New household robots provide technical assistance at various levels. A desktop robot helps the severely handicapped to spoon food from a plate (Bestic, 2013), or the human-robot ASIMO serves drinks or puts the dishes into the dishwasher (ASIMO, 2013). These new technologies, which have their origins in Ubiquitous Computing (Weiser, 1991) as well as Ambient Intelligence (Information Society Technologies Advisory Group, 1999), could also serve to improve quality of life and enhance independent living (Georgief, 2008; Stephanidis, 2009; Streitz, 2010). Technologies that accomplish those tasks are summarized under the term of "Ambient Assisted Living" (Becks et al., 2007; Giesecke et al., 2005).

AAL refers to "intelligent systems that will assist elderly individuals for a better, healthier and safer life in the preferred living environment and covers concepts, products and services that interlink and improve new technologies and the social environment" (European Ambient Assisted Living Innovation Alliance, 2010). The central aim of AAL is to enable the elderly to live an independent life in their own accustomed living environment. The technology operates automatically and unobtrusively in the background. Since AAL is developed as assistance technology for a safe and longer life at home, the credibility of this technology influences the usage. For example, if a person falls down and remains lying unconscious on the floor, the end user of the AAL, as well as the relatives, has to rely on the fact that the technology is reliable in such an emergency case. AAL technology, which acts in the background, has to be reliable and trigger the alarm immediately in order to start the emergency reaction process. Another example of a critical situation that can occur in the household is fire.

A study shows that around 200,000 reported fires in Germany per year cause approximately 600 deaths (Stiftung Warentest, 2002). Further data for the United Kingdom show that every year 500 people die as a result of domestic fires and more than 13,000 are injured (Blazescape, 2012). In addition to these facts, a further study (Jonsson & Bergqvist, 2013) reveals that in Sweden the number of people who die as a result of fires increases with age. Supplementary to smoke detectors, which make a noise in case of fire, stove sensors in AAL technologies are developed to turn off the stove automatically in case someone has forgotten to turn it off manually (Becks,

Eberhardt, Heusinger, Pongratz, & Stein, 2010). In cases of these critical situations just described, people will not use the technology if they are not convinced that it works in the correct manner. Moreover, in other noncritical examples, such as closing the windows automatically via remote control, the end user should trust that the technology functions. As AAL technology is often sustained by a human service provider, this interconnected system will be influenced by technological and interpersonal trust.

2.2. Technological and Interpersonal Trust

One type of trust is technological trust—so-called trust in automation. Parasuraman and Riley (1997, p. 231) defined automation as "execution by a machine agent (usually a computer) of a function previously carried out by a human." As this type designates a human's trust with a technology or device (Muir, 1994), the main difference to other types of trust is that the trustee, in this case, is a machine. New technologies become increasingly complicated, and humans cannot cope with the full degree of complexity. Humans cannot fully understand the processes behind the results of automation. Still, they have to rely on automation to use it in an adequate manner (Masalonis & Parasuraman, 1999). Therefore, trust can be seen as a mediator between humans and automation by guiding reliance (Lee & See, 2004). In a human–human relationship, trust will erode if the trustor recognizes that the trustee always has the best intentions but his or her behavior does not reflect this intention (McKnight, Cummings, & Chervany, 1998).

In addition to the concept of trust in automation, a brief remark on the concept of interpersonal trust should be mentioned. Generally, interpersonal trust is separated into two types that can be seen in the differences between the views of Rotter (1971) and Rempel, Holmes, and Zanna (1985). These become apparent when comparing the scope of the trustee. Whereas Rempel et al. (1985) investigated trust in "close relationships," Rotter (1971) used the "interpersonal trust scale" to measure a general disposition in the person to see the degree of trust in general interactions in social life. Trust in a particular person may vary from one situation to another and is strongly influenced by the trustee's previous behavior. Pilots, as well as health care givers, nurses, and physicians, are professions connected to high personal trust. Nevertheless, these people can also make mistakes or handle technology in an incorrect manner, which leads to lower trust in this occupational group on subsequent occasions. Buck and Bierhoff (1986) also stressed the fact that interpersonal trust is not constant over time and depends on the degree of emotional bonding toward the other person. Thus, it would not be possible to predict the degree of trust in a specific situation by drawing from general dispositions. In the context of AAL, unexpected situations arise, which increase the importance of considering trust.

An AAL application can be seen only as a substitute for a supporting professional but obviously not for a friend or family member. The present study does not compare technological versus interpersonal trust but rather technological versus a hybrid form of both trust types. PRA, as well as the embedded technical support function, will be used for gaining new insights into trust in AAL technology.

3. METHODOLOGY

The experiment used in the present article is based on results from a previous questionnaire survey with 292 participants (M age = 74.39, SD = 10.01; Steinke, Bading, Fritsch, & Simonsen, 2014). According to the trust model of Lee and Moray (1992), trust is not based on a single event but rather an accumulated number of events. To gain a more generalizable evaluation within this former study, older adults were asked about their trust and different other variables in two AAL scenarios in the domestic environment. The first scenario characterized an emergency case within the apartment, in which a person fell down and was injured. The other scenario described a situation in which a person forgets to turn off the stove and the AAL technology received his or her attention (Steinke et al., 2014).

Following these scenarios, the tasks in the present experiment are also embedded, in situations that may emerge in a household, to convey the benefit of the AAL technology to the users. User surveys within the research project SMILEY revealed different useful fields of application for elderly end users (Fraunhofer ISST, 2013). Due to the fact that the experimental design cannot realistically cover an emergency situation such as a person falling, the authors have focused on three realizable scenarios for the experiment. As previously described, home fires are dangerous to the lives of residents and might be better controlled by stove sensors. Therefore, the first scenario included the operation of stove sensors. The two further experimental tasks included the control functions of windows and lights in an integrated AAL technology. These functions provide the possibility to make the house safer, as well as appearing inhabited, and can be seen as an entry point for more critical AAL solutions.

3.1. Sample

After conducting a preliminary study with five students, the experiment was conducted with an intervention and a control group. For the intervention group, 32 participants, whose minimum age was 60 years, were recruited. Due to the fact that AAL technology is developed especially for extending independent life in private homes, all of these older participants are still living in their own apartments. For the control group, younger participants were recruited via the university in Munich. A total of 21 students agreed to participate in the study. In all, 53 persons participated in the experiment. The intervention group of elderly persons (n = 32; M age = 69.84, SD = 6.31) was randomly divided into one group with PRA (n =

15) and another group with ETA ($n = 17$) before the experiment started. The control group with younger participants ($n = 21$; M age = 24.71, $SD = 2.10$) was only investigated with the ETA. The percentage distribution of women was approximately 60% in all three groups. Whereas in the control group all persons own a personal computer, 25% of the persons in the intervention group do not. This value of computer ownership corresponds to the benchmark of older people (up to 70 years) in Germany (Statistisches Bundesamt, 2011). In addition, 38% of the younger people possess a tablet computer, whereas only 12.5% of the older people own one.

As an indicator for computer literacy, the numbers of hours participants spend at the computer per week were also measured. This indicator is also used in the computer literacy scale by Sengpiel and Dittberner (2008). Regarding this data, the most obvious difference can be seen in computer usage per week. Older people use their computer, on average, 6.45 hr per week, and younger participants, in comparison, nearly 60 hr per week (see Table 1).

3.2. Apparatus

The participants will have to use a mock-up of an AAL application. The mock-up was running on the tablet PC Fujitsu Stylistic Q550 (1.70 GHz, 2.00 GB RAM with Windows 7) in order to fulfill three tasks from daily life. It is operated via a touch screen. In a second room, there was another person, and this simulated the service provider for the PRA group. This person used a laptop computer with Windows 7 and a headset for communicating via a video telephone.

3.3. Experimental Design

For the present study, a between-group design was selected. This design seems to be most adequate—otherwise participants would undergo two rounds of the experiment with two treatments with repeated measures (Field & Hole, 2011). As described before, the between-group design splits the sample into an intervention group with PRA and a second group with embedded technical support. To prevent the occurrence of any systematic differences, the older participants were randomly assigned to their groups. Moreover, a control group with younger participants, who undertook the experiment only with ETA, was analyzed. The measurements were made on the basis of the execution of the experiment (behavioral data) and by an additional questionnaire (for details, see section 3.5).

3.4. Task Description and Procedure

The three tasks within the experiment are all embedded in situations that may emerge in a household. These scenarios would be manageable with the module "Meine Wohnung" (my home) from the original prototype application (Fraunhofer ISST, 2013). The participant has to solve each task within 10 min. The AAL application should be used to handle the three situations (for details, see Table 2).

In the stove scenario, the participant's task is to use the mock-up to control whether the stove is turned off correctly. If the stove is still found to be on, the task is to turn off the stove. In the light scenario, the participant has to use the application to switch on the lights to simulate being at home. In the third task, the participant should control the window in the bedroom. If the window is still open, the task is to close it.

Figure 1 shows screenshots from the experiment. The start menu, as well as the overview of all the rooms, is used for all of the three tasks. The picture on the right side displays the stove task in the kitchen and the checking operation.

All participants have to solve all three tasks: stove, light, and window. The measurement of trust via the questionnaire takes place after each task. To prevent the order of tasks affecting the evaluation, the participants are counterbalanced according to a Latin square (Hinkelmann & Kempthorne, 2007; Vogel & Zendler, 2009). By using permutation in the experimental order, it is guaranteed that the participants are equally distributed among the three different task orders (see Ingenhoff, 2012).

TABLE 1
Descriptive Statistic Sample Including Computer Experience

	Overall Sample Elderly	Elderly[a]		Junior[b]
		PRA Group[c]	ETA Group[d]	ETA Group
Age (M, SD)	69.84 (6.31)	71.33 (6.63)	68.53 (5.90)	24.71 (2.10)
No. of women	19 (59.38%)	9 (60.00%)	10 (58.82%)	12 (57.10%)
No. of men	13	6	7	9 (42.90%)
No. of people living alone	10 (31.25%)	7 (46.67%)	3 (17.65%)	3 (14.30%)
No. of people with no computer	8 (25%)	4 (26.67%)	4 (23.53%)	0 (0.00%)
Years of computer ownership (M)	12.28	11.67	12.82	14.80
Use of computer (M hr/week)	6.45	7.83	5.22	59.43
No. of people owning a tablet	4 (12.5%)	1 (6.67%)	3 (17.65%)	13 (61.9%)

Note. PRA = personal remote assistance; ETA = embedded technical assistance.
[a] $n = 32$. [b] $n = 21$. [c] $n = 15$. [d] $n = 17$.

TABLE 2
Short Descriptions of the Three Scenarios

Task stove
Imagine you lived in a multifamily house apartment. After having prepared and eaten lunch you are visiting acquaintances from another town. When you arrive, you start to doubt if you have turned off the stove correctly. Recently, there was an article in the news about house fires. All your belongings and your life would be in danger. [. . .]
Task light
Imagine you lived in a detached house. Recently, people have reported burglaries in your neighborhood. As you want to leave your house in order to go on vacation for two weeks, you want the house to appear inhabited by using lights. Thanks to sensors in the lighting system, you can switch different lights on and off in your house as you desire. [. . .]
Task window
Imagine you are visiting your relatives and you plan to stay overnight at their house due to the long distance. In the evening, you watch the weather forecast on TV and realize that a storm will reach your hometown. You are uncertain whether you closed all of the windows properly or not. The bad weather makes it impossible to return to your home and close the windows manually. [. . .]

The participants are randomly assigned to one of the following two intervention groups: (a) group with PRA, or (b) group with ETA. The PRA aims to help the participant fulfill the task in a case where the participant feels insecure about the right handling of the AAL application. The simulated service provider can communicate with the participant on the AAL application surface by video telephone and can tell the participant where to click, as well as even actively click on the desired icons via remote control. This remote assistance occurred in two ways—as a push-and-pull support. The "push" support is activated automatically after 5 min. The simulated service provider then appears in the upper-right corner of the display and asks if the participant needs support. The participant decides which way the support will be used. Remote support, as a "pull" function, can also be activated before the 5 min have expired by saying the keyword "help" in the direction of the tablet computer.

In contrast, the group with ETA only received support by a push function. After 30 s, the technical support function highlighted the button, which has to be tapped by the participant. In a case in which the participant does not know which button has to be clicked next, or clicks the wrong button, the technical support gives a hint that the task can be solved successfully. The time until the assistance was initiated automatically resulted from the preliminary study as well as discussions with older people in the context of former studies.

Because the original application was, so far, not capable of being linked to electronic appliances, a "camera view" was integrated into the three experimental tasks. This camera view of stove, lights, and window are in fact pictures, which have been shot before and show the corresponding status. The participants get the information that is parallel to the operation of the application on the tablet computer—the action is accomplished in reality. For example, if the participant turned off the left hot plate, the mock-up displays an image of a left hot plate where the red indicator lamp is off.

In fact, the technology is not performing the task. Nevertheless, to check if the action was finished correctly, the participant is given the opportunity via a "checking operation," which is integrated into the AAL application to monitor the state of the appliance. To prevent the checking button being pushed for reasons of curiosity, additional hurdles are implemented. This artificial barrier consists of four mathematical tasks, which have to be solved in order to receive the

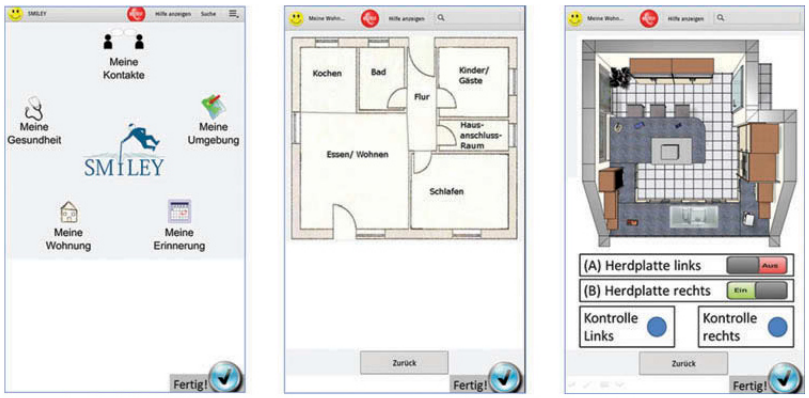


FIG. 1. Screenshot from the Ambient Assisted Living mock-up.

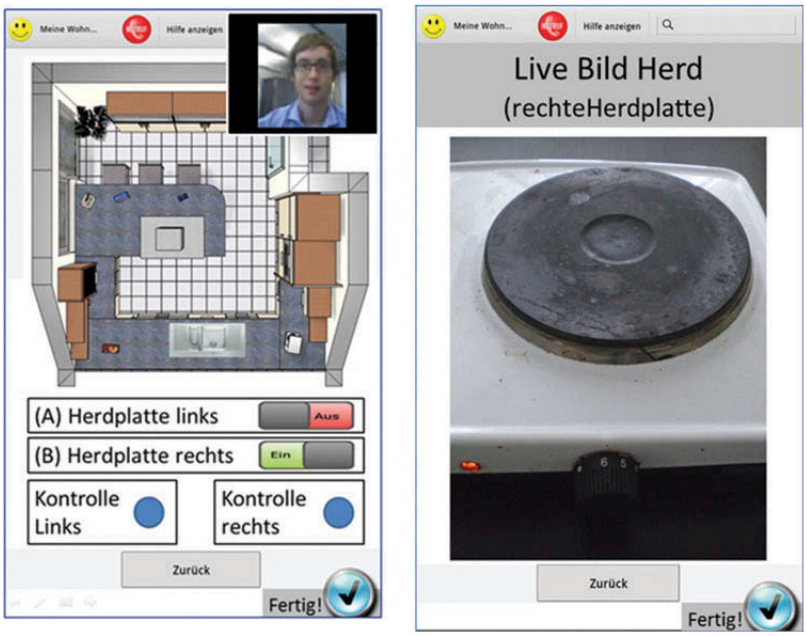


FIG. 2. Screenshot from the Ambient Assisted Living mock-up.

camera view. In comparison, Ho, Wheatley, and Scialfa (2005) also applied mathematical tasks in their experiments to distract the participants from a medication task. To receive the desired picture of the item, the participant has to solve four different calculation tasks within each scenario. The calculated numbers work like a transaction number from online banking and thus provide additional security. The arithmetical problems were read to the participant to increase additional barriers again. Furthermore, both of the former mentioned types of assistance were not given in the checking operation, so the participants had to calculate the mathematical tasks by themselves in order to get the camera view. Figure 2 shows a screenshot of the AAL mock-up with personal assistance in the PRA condition as well as the camera view within the stove task.

3.5. Variables and Measurement

The present study reveals, on one hand, behavioral data, as well as subjective variables by a questionnaire on the other hand. The participants' performance can be measured by the percentage of task solving, number of clicks per task, and the time required per task. Moreover, the number of checking operations, as well as the number of push and pull actions in PRA, are gained by observation. The variable trust in AAL (T_{AAL}) was measured by a questionnaire—derived from the scale by Jian, Bisantz, and Drury (2000). Because the original scale is written in English, it had to be translated into German. The degree of trust is expressed on a 7-point Likert scale (as in the original version).

The results of the study of Steinke et al. (2014) show that the variables—"perceived ease of use" (PEOU), "perceived usefulness" (PU), "expected reliability" (ER), and "intention to use" (IU)—are significantly linked to T_{AAL} (Steinke et al., 2014). With the exception of the variable ER, which is substituted by "perceived reliability" (PR) since participants had evaluated their experiences with AAL reliability in the current experiment, the same questionnaire is used. All of these variables are measured by questionnaire after the experiment. A 7-point Likert scale is applied again.

4. RESEARCH HYPOTHESES

Through the experiment, as well as the participants answering the questionnaire from Steinke et al. (2014), the following seven hypotheses are investigated. These hypotheses focus on type of assistance, trust in AAL technology, perceived ease of use, intention to use, seniority, and its influence among themselves as well as on further variables.

4.1. Type of Assistance

As described before, the present study differentiates between two types of assistance in the context of an AAL application: PRA and ETA. As seen in the context of interactive voice response systems (IVRs), older people prefer personal

interaction and speaking to a real person on telephone hotlines instead of automated computer voices. Moreover, old age influenced performance negatively and usability ratings of IVRs are lower in contrast to younger people (Dulude, 2002). Experiences with IVRs are also seen as frustrating and unpleasant for older. Furthermore, a guided error training for ticket vending machines shows that video help was better evaluated with reference to type of support and comprehensibility (Struve & Wandke, 2009).

Following these results, in connection with AAL technology, which supports older people in their home environment, it can be assumed that PRA will also be preferred by the end user in contrast to ETA. In particular, the fact that personal details in case of emergency will be transmitted leads to a stronger need for personal assistance. This social support via PRA may not only be helpful in emergency situations but also in general questions regarding the AAL solution, for example, in cases of battery replacement. Therefore, the main hypothesis is set up as follows:

H1: (a) Trust, (b) perceived ease of use, (c) intention to use, and (d) the amount of solved tasks by elderly people is positively influenced by PRA.

4.2. Trust in AAL Technology

Steinke et al. (2012, p. 81) defined trust in AAL as "the attitude that an assistive technology supports an impaired person within [its] social environment in an uncertain and vulnerable situation." In the present study, this uncertain situation is described by the three different AAL scenarios in which the participant is put in a worrying situation. As technological systems become increasingly complicated, humans cannot evaluate the true technological capabilities of the system but base their trust level, for example, in which way they interact with the system. Many studies claim that trust in automation is higher than trust in humans (Dijkstra, Liebrand, & Timminga, 1998; Dzindolet, Pierce, Beck, & Dawe, 2002; Lee & Moray, 1992; Wiegmann, Rich, & Zhang, 2001). In contrast to these results, Lerch et al. (1997) showed that the confidence in a human expert's advice was higher than in an expert computer system. Regarding AAL, the interdependence of technical support by sensors and personnel supported by a human service provider—as a doctor in an emergency situation—clarifies that technical, as well as personal, trust by the end user has to be available in case of actual usage. Previous results reveal significant connections between perceived ease of use, perceived reliability, and perceived usefulness and trust in AAL technology (Steinke et al., 2014). Furthermore, the link between using the checking operation and trust will be analyzed. Thus, the following hypotheses can be derived:

H2: Trust of elderly persons in AAL technology is positively influenced by (a) perceived ease of use, (b) perceived reliability, and (c) perceived usefulness, but negatively influenced by (d) the number of checking operations.

H3: Trust in AAL technology in the overall sample is positively influenced by (a) perceived ease of use, (b) perceived reliability, (c) perceived usefulness, and (d) being elderly, but negatively influenced by (e) the number of checking operations.

4.3. Perceived Ease of Use

Adapting from the technology acceptance model (TAM) by Davis (1989), perceived ease of use can be defined as "the degree to which a person believes that using a particular system would be free of effort" (Davis, 1989). User-friendliness and comprehensibility aim people toward acting with technology in the way they want. Particularly, older people have special requirements for technology. The study by Fraunhofer ISST (2013) reveals that, from 50 participants (M age = 71.0), 90% expect that AAL technology is easy to handle and 88% expect additional comfort to be useful. A total of 54% have concerns about AAL technology because of the difficult handling (Fraunhofer ISST, 2013). Following this argumentation, solving the tasks in the present experiment is influenced by perceived ease of use as described in the next hypothesis.

H4: Perceived ease of use in AAL technology is positively influenced by the amount of tasks solved.

4.4. Intention to Use

The behavioral intention to use technology is a well-examined variable within the TAM (Davis, 1989; Ma & Liu, 2004; Schepers & Wetzels, 2007; Yousafzai, Foxall, & Pallister, 2007). Intention to use characterizes a person's determination, and it is upstream to the actual behavior. As seen in Steinke et al. (2014), intention to use was influenced by variables such as interest in technology, perceived health status, and trust in AAL technology. The present article takes this scenario-based approach and analyzes trust and perceived usefulness as influencing factors on older adults' intention to use in an experimental design. Ghazizadeh, Peng, Lee, and Boyle (2012) also revealed a significant connection between trust and intention to use in an on-board monitoring system by an extended TAM (Ghazizadeh et al. 2012). Although AAL technology has been explored for the past 8 years, a marketable solution is yet to emerge (Steinke et al., 2014). Thus, it is already important to critically question the influence on intention to use. Following the former results, the following hypothesis can be assumed:

H5: Elderly people's intention to use is positively influenced by (a) trust in AAL technology and (b) perceived usefulness.

H6: Intention to use in the overall sample is positively influenced by (a) trust in AAL technology, (b) perceived usefulness, and (c) being elderly.

4.5. Seniority

To get a better understanding of the differences between younger and older people in the present analysis, it is necessary to take a closer look at the term "seniority." There are different age definitions within science. Age is not readily defined by the date of birth; the chronological age of two persons may be equal, but the biological, psychological, or social age may differ (World Health Organization, 2011). As seen in the descriptive data, it can be expected that older people have less knowledge of technology, and some of them are not familiar with handling a computer or tablet PC. Due to this fact, Steinke et al. (2014) showed that there is no significant connection between chronological age and trust, as well as intention to use, and in the present study an additional separation of younger and older people is investigated. The differentiation between the intervention and control groups regarding PEOU and PU are analyzed by the following hypothesis:

H7: (a) Perceived ease of use and (b) perceived usefulness are positively influenced by being elderly.

5. RESULTS

The following section gives an overview of the results of the study. First, behavioral data, as a percentage of task solving and investment of time for the different tasks, are analyzed. Thereby, a major focus lies in the differentiation between PRA and ETA in the intervention group—as well as the comparison with the younger people in the control group. Afterward, the results from the different variables from the questionnaire are analyzed. The analysis is conducted using descriptive statistics as well as analyses of variance and ordinary least squares regressions.

5.1. Behavioral Data

Task processing. The first evaluation shows the percentages of tasks solved in the different scenarios as well as the number of participants who received assistance via push or pull actions. As seen in Table 3, in the intervention group, 80% of the test persons solved the "stove" task, 73.3% solved the "window" task, and 66.7% solved the "lamp" task correctly. Each of the 21 younger people of the control group solved the stove and window tasks, and 76.2% solved the lamp task correctly. Errors in task processing occurred, for example, due to participants' misunderstanding the task. Furthermore, some of the participants had difficulties handling the tablet. Unsuccessful task solving can result from pushing the finish button prematurely or from not finishing the task within 10 min (e.g., not solving the optional checking operation in time).

TABLE 3
Data of Successful Solved Tasks and Received Assistance Among the Three Scenarios

	Elderly[a]		Younger[b]
	PRA Group[c] % (No. of Participants)	ETA Group[d] % (No. of Participants)	ETA Group % (No. of Participants)
Stove	80.0 (12)	41.2 (7)	100 (21)
Lamp	66.7 (10)	29.4 (5)	76.2 (16)
Window	73.3 (11)	35.3 (6)	100 (21)

Note. PRA = personal remote assistance; ETA = embedded technical assistance.
[a]$n = 32$. [b]$n = 21$. [c]$n = 15$. [d]$n = 17$.

It should be mentioned that only approximately 53% of the people with personal support, and 12% of participants with technical support, solved all of the tasks correctly. More than 76% of the junior control group solved all of the tasks.

Moreover, there are some mentionable correlations regarding the successful completion of the scenarios. First, elderly people gained experience of solving the tasks during the experiment. Whereas 50% of the participants correctly solved their first and second task, 59.4% solved the third task. Second, solving one task is positively correlated with solving the other tasks as well. On the other hand, task solving is positively correlated with T_{AAL} ($r = .314$), PEOU ($r = .636$, $p < .01$), PU ($r = .122$), PR ($r = .277$), and IU ($r = .213$).

An ANOVA is conducted for the question of whether an elderly participant, who successfully solves the tasks, differs in his or her evaluation regarding T_{AAL}, IU, PEOU, PU, and PR. For this analysis, two different assumptions are applied: (a) successful task solving means solving at least two tasks successfully; and (b) successful task solving will be defined as having solved all tasks successfully.

Those who succeeded in "solving at least two tasks correctly" differ from those who did not—considering T_{AAL} ($p < .05$) and PEOU ($p < .005$), but not regarding IU, PU, and PR. On the other hand, when defining task solving as solving all tasks correctly, only between-group differences in the evaluation of PEOU ($p < .05$) are significant, indicating that solving a task increases the subjective perceived ease of use. Furthermore, when considering PRA and ETA, participants receiving PRA differ in their probability of solving the tasks when compared to those with ETA ($p < .01$).

Number of clicks and investment of time. Table 4 shows the differences of the average actual clicks between the three scenarios and the different experimental groups. The number of clicks was measured for each task until the participant had finished the task by clicking on the finish button or the task was

TABLE 4
Number of Clicks Among the Three Scenarios

	Elderly[a]				Younger[b]	
	PRA Group[c]		ETA Group[d]		ETA Group	
	M	Min./Max.	M	Min./Max.	M	Min./Max.
Stove	34.9	7/123	31.8	10/73	11.3	6/19
Lamp	35.6	12/136	24.6	11/60	15.5	9/44
Window	22.7	6/89	27.0	9/69	10.2	5/26

Note. PRA = personal remote assistance; ETA = embedded technical assistance.
[a]$n = 32$. [b]$n = 21$. [c]$n = 15$. [d]$n = 17$.

TABLE 5
Average Duration for Finalizing the Three Scenarios Among the Three Scenarios in Minutes

	Elderly[a]		Younger[b]
	PRA Group[c]	ETA Group[d]	ETA Group
Stove	4.9	5.4	2.19
Lamp	5.1	5.1	1.8
Window	4.0	5.7	1.7

Note. PRA = personal remote assistance; ETA = embedded technical assistance.
[a]$n = 32$. [b]$n = 21$. [c]$n = 15$. [d]$n = 17$.

automatically finished after 10 min—in both cases no matter if the tasks were solved correctly. The minimum number of clicks, which is calculated for the direct way to solve the tasks, is five clicks for the window task, six clicks for the stove task, and nine clicks for the lamp task. Regarding usage of the checking operation, the minimum number increases to 14 clicks in the window scenario and 24 and 27 clicks in the stove and lamp scenarios, respectively. The reason for this difference in minimum clicks is, on one hand, the fact that the window scenario required only one action to be performed (closing one window), and the other two scenarios required two actions. On the other hand, there was a slight variation in each room to avoid the participants falling into a pattern. The minimum number of clicks was equal for PRA and ETA.

The intervention group with PRA shows the range of the average actual number of clicks from 22.7 (window) to 35.6 (lamp). In contrast, older participants with ETA needed, on average, 24.6 (lamp) to 31.8 (stove) clicks until the end of the task. The number of average clicks in the control group ranged from 10.2 (window) to 15.5 (lamp). The number of minimum clicks by the older participants was between six (window) and 12 (lamp). In contrast, the maximum clicks ranged between 89 (window) and 136 (lamp). The control group reached a maximum number of clicks from 19 (stove) to 44 (lamp).

As mentioned before, through the number of measured clicks, in this descriptive evaluation regarding the duration, participants did not necessarily answer the tasks correctly. They pressed the "finish" button or the time of 10 min elapsed. As seen in Table 5, there are also differences in the average times required by the intervention and control groups to finish the tasks. The younger control group needed around 2 min, on average, before pushing the finish button, and the intervention group with ETA required between 5 and 6 min. The average duration with PRA is from 4.0 (window) to 5.1 (lamp) min.

Regarding the number of clicks a person needed in order to solve a task, the analysis revealed several interesting results. First, no reduction of clicks was observed. Elderly participants, on average, executed 29.68 ($SD = 23.11$) clicks to solve their first task. For the second and third task, 28.23 ($SD = 24.00$) and 29.94 ($SD = 20.00$) clicks were executed, respectively. Second, the number of clicks was negatively correlated with the experience the participants had with computers and tablet PCs. Third, the number of clicks was positively correlated with the time needed and negatively correlated with the correct solution of tasks. Fourth, the mean number of clicks was positively (but not significantly) correlated with the evaluation of the technology, that is, with T_{AAL} ($r = .185$), PEOU ($r = .209$), PU ($r = .209$), PR ($r = .225$), and IU ($r = .157$). This indicates that people who executed a higher number of clicks (e.g., because they had problems with solving the tasks or because they used the checking operation) generally had a higher opinion of T_{AAL}, PEOU, PU, PR, and IU.

With respect to the time needed to solve each task, the analysis revealed a negative correlation with the correct solution of the tasks (correlations up to −.43). Second, the longer the participant needed the higher he or she evaluated the technology, that is, the time needed for solving the tasks is often (though not significantly) positively correlated with T_{AAL} ($r = .090$), PU ($r = .268$), PR ($r = .134$), and IU ($r = .288$).

Checking operation. To find out whether checking for a correctly working system (clicking on the checking button) influences the evaluation of the system, it has to be differentiated between several definitions of checking. In each scenario, data were collected about whether the participant started the checking operation and whether he or she finished it. Finishing the operation means that four different arithmetical problems were solved correctly by the participant and the camera view was displayed. Two reasonable definitions of using the checking operation are then analyzed. Checking as a variable is defined as (a) participants having started the check, but without finishing at least one scenario; and (b) successfully executing the checking operation until the end of at least one scenario.

The share of participants starting or executing the checking operation can be found in Table 6.

Following the results, the relevance of the additional checking operation is highlighted. The correlation analysis regarding the checking operation revealed several important aspects. First,

TABLE 6
Share of participants starting or executing the checking operation

	Elderly[a]				Younger[b]	
	PRA Group[c]		ETA Group[d]		ETA Group	
Task	Started	Executed	Started	Executed	Started	Executed
Stove	35.3%	29.4%	40.0%	26.7%	38.1%	19.0%
Lamp	41.2%	11.8%	26.7%	20.0%	19.0%	9.5%
Window	17.6%	52.9%	33.3%	20.0%	28.6%	14.3%

Note. PRA = personal remote assistance; ETA = embedded technical assistance.
[a]$n = 32$. [b]$n = 21$. [c]$n = 15$. [d]$n = 17$.

using the checking operation for a working system in one of the three scenarios correlates with checking this function in other scenarios as well (correlations between .34 and .61). Second, checking is not always correlated positively with solving the tasks correctly—sometimes even negative correlations appear (nonsignificant correlations ranging from −.030 to .129). Third, neither T_{AAL} nor PU, PR, and IU show a significantly positive relationship with checking for a working system (correlations ranging from −.056 to .381). For the senior sample, a significant correlation of .381 ($p < .05$) between starting the checking operation and T_{AAL} was revealed. Executing the checking operation successfully was nonsignificant—as well as the correlations in these two relations for the overall sample. The ANOVA reveals trust differences between participants starting the check and those who do not start the check ($p < .05$) as well as differences between those finishing the check and those not finishing it ($p < .01$).

TABLE 7
Descriptive Analysis by Mean Values

	Overall Sample Elderly	Elderly[a]		Younger[b]
		PRA Group[c]	ETA Group[d]	ETA Group
T_{AAL}	5.74	5.99	5.52	5.53
PEOU	4.73	5.50	4.05	6.00
PU	5.46	5.40	5.51	4.57
PR	5.39	5.61	5.20	5.02
IU	5.50	5.58	5.43	4.97

Note. PRA = personal remote assistance; ETA = embedded technical assistance; T_{AAL} = trust in Ambient Assisted Living; PEOU = perceived ease of use; PU = perceived usefulness; PR = perceived reliability; IU = intention to use.
[a]$n = 32$. [b]$n = 21$. [c]$n = 15$. [d]$n = 17$.

5.2. Questionnaire Data

After analyzing the behavioral data from the experiment, the variables—which are requested via the questionnaire in the case of T_{AAL} after each scenario, and PEOU, PU, PR, and IU after the overall experiment—are investigated. Table 7 gives a visual overview of the mean values in the questionnaire resulting from the experiment.

The results of T_{AAL} in the three different scenarios (stove, lamp, and window) are considered. All three tasks were evaluated by the maximum possible measure of seven by at least one person. The minimum measures vary to a large extent between the groups. The means of T_{AAL} in the stove, lamp, and window tasks are 5.89 ($SD = 1.01$), 5.65 ($SD = 1.23$), and 5.67 ($SD = 1.09$), respectively.

To evaluate trust as a single variable, for further analysis the three single items from the different AAL scenarios are merged to their total mean score, which represents the overall trust in the AAL application. In consequence, no further differentiated analysis of the three different scenarios will take place. The accumulated trust mean score of the elderly is 5.74—with a standard deviation of 1.03. The perceived ease of use of the technology was evaluated with an average value of 4.72 ($SD = 1.64$). The value of perceived usefulness was, on average, 5.46 ($SD = 1.18$), that of perceived reliability 5.39 ($SD = 1.20$), and the value of intention to use 5.50 ($SD = 1.40$).

To find out whether differences in the perception of older people between PRA and ETA exist, an ANOVA is executed for the variables T_{AAL}, PEOU, PU, PR, and IU while distinguishing between persons with PRA and ETA. The only variable in the present experiment significantly influenced by PRA is PEOU ($p < .05$). The other variables—T_{AAL}, PU, PR, and IU—are not significantly influenced by PRA (see Table 8).

To indicate the influence of PEOU, PU, and PR on T_{AAL}—based on the results by Steinke et al. (2014)—a multiple regression was conducted with T_{AAL} as dependent, and PEOU, PU, and PR as independent, variables (Table 9), which on a 5% level revealed a significant influence of PR and PEOU on T_{AAL}. The multiple regression regarding IU as the dependent, and T_{AAL}, PEOU, PU, and PR as independent, variables reveals that PU ($p < .001$) is the only variable significantly influencing IU (Table 10).

After analyzing the data of the intervention group, the question arises as to what extent the sample of the younger participants differs from that of the elderly. Hence, the following results show the differentiation between the younger and older participants. Considering the variables PEOU, $F(1, 51) = 10.176$, $p < .005$, and PU, $F(1, 51) = 7.426$, $p < .01$, there is a significant difference between younger and older participants. On the other hand, T_{AAL}, PR, and IU do not significantly differ across both age groups. Moreover, the correlations between being elderly and PEOU is −.408 ($p < .001$) and between being elderly and PU is 0.357 ($p < .001$).

Moreover, regression analyses are conducted for the overall sample regarding the variables' influence on T_{AAL} and IU. The

TABLE 8
Analysis of Variance Regarding Personal Remote Assistance (Senior Sample)

	Sum of Squares	df	M Square	F	Sig.
T_{AAL}					
Between Groups	1.798	1	1.798	1.743	.197
Within Groups	30.959	30	1.032		
Total	32.757	31			
PEOU					
Between Groups	16.635	1	16.635	7.525	.010
Within Groups	66.319	30	2.211		
Total	82.953	31			
PU					
Between Groups	.101	1	.101	.070	.793
Within Groups	43.113	30	1.437		
Total	43.214	31			
PR					
Between Groups	1.387	1	1.387	.960	.335
Within Groups	43.355	30	1.445		
Total	44.742	31			
IU					
Between Groups	.171	1	.171	.084	.774
Within Groups	60.940	30	2.031		
Total	61.111	31			

Note. T_{AAL} = trust in Ambient Assisted Living; PEOU = perceived ease of use; PU = perceived usefulness; PR = perceived reliability; IU = intention to use.

TABLE 9
Regression on Trust in Ambient Assisted Living (Senior Sample)

	Unstandardized Coefficients		Standardized Coefficients		
Model	B	SE	Beta	t	Sig.
1					
(Constant)	3.601	.731		4.928	<.001
PEOU	.254	.104	.404	2.439	.021
PU	−.311	.196	−.357	−1.588	.124
PR	.489	.210	.571	2.323	.028

Note. PEOU = perceived ease of use; PU = perceived usefulness; PR = perceived reliability.

results of the regression analysis further reveal that PEOU and PR are significant indicators ($p < .05$ and $p < .005$, respectively) for T_{AAL} in the total sample. Considering IU, the total sample results indicate that only PU is influential on IU ($p < .001$), whereas T_{AAL}, PEOU, and PR are not.

TABLE 10
Regression on Intention to Use (Senior Sample)

	Unstandardized Coefficients		Standardized Coefficients		
Model	B	SE	Beta	t	Sig.
1					
(Constant)	.132	1.184		.112	.912
PEOU	.156	.136	.181	1.146	.262
PU	1.014	.243	.853	4.178	<.001
PR	−.288	.273	−.246	−1.057	.300
T_{AAL}	.113	.224	.083	.504	.618

Note. PEOU = perceived ease of use; PU = perceived usefulness; PR = perceived reliability; TAAL = trust in Ambient Assisted Living.

6. DISCUSSION

The present article differentiates between PRA and ETA as forms of support in an experiment with an AAL mock-up. These two types of assistance help the participants to solve the experimental tasks. Despite the fact that the ETA highlights the button that the participant is required to push on the tablet computer, and thus functions 100% reliably in this experiment, the elderly preferred the PRA. Perceived ease of use is positively influenced by PRA—thus, hypothesis H1b can be verified (all hypotheses can be seen again in Table 11). The reason could be the low number of older people who already had experience with tablet computers. Only four of the 32 participants are owners of a tablet computer—and only one in the PRA group. Therefore, support by a human operator, even if it is through a video telephone, seems to be more comfortable than technical support by highlighted buttons alone.

Despite these positive results, neither the correlation between trust and PRA nor those of intention to use and PRA are statistically significant (H1a and H1c can be rejected). This means that the main research question "Does a significant relationship exist between elderly people's trust and the type of assistance integrated in an AAL application?" can be answered with a "no." There is a positive correlation, but not statistically significant, which could be substantiated by the small sample size.

The fact that approximately 53% of the older people with PRA, but only 12% of participants with ETA, solved all of the tasks correctly shows a huge difference between the two assistance types. The amount of solved tasks is positively influenced by PRA (H1d can be verified). For the overall sample, perceived ease of use is significantly linked to the number of solved tasks (H4 can be verified). This indicates that PRA, integrated into AAL technology, could be an important factor in increasing user-friendliness. Consequently, this could be used as a marketing opportunity for AAL to lead more people toward buying this technology.

TABLE 11
Hypothesis Test

	Hypothesis	Support
Results from senior sample		
H1a	Trust in AAL is positively influenced by PRA	No
H1b	Perceived ease of use is positively influenced by PRA	Yes
H1c	Intention to use is positively influenced by PRA	No
H1d	Amount of solved tasks is positively influenced by PRA	Yes
H2a	Trust in AAL is positively influenced by perceived ease of use	Yes
H2b	Trust in AAL is positively influenced by perceived reliability	Yes
H2c	Trust in AAL is positively influenced by perceived usefulness	No
H2d	Trust in AAL is negatively influenced by the number of checking operations	No
H4	Perceived ease of use is positively influenced by amount of tasks solved	Yes
H5a	Intention to use is positively influenced by trust in AAL	No
H5b	Intention to use is positively influenced by perceived usefulness	Yes
Results from overall sample		
H3a	Trust in AAL is positively influenced by perceived ease of use	Yes
H3b	Trust in AAL is positively influenced by perceived reliability	Yes
H3c	Trust in AAL is positively influenced by perceived usefulness	No
H3d	Trust in AAL is positively influenced by being elderly	No
H3e	Trust in AAL is negatively influenced by the number of checking operations	No
H6a	Intention to use is positively influenced by trust in AAL	No
H6b	Intention to use is positively influenced by perceived usefulness	Yes
H6c	Intention to use is positively influenced by being elderly	No
H7a	Perceived ease of use is positively influenced by being elderly	No
H7b	Perceived usefulness is positively influenced by being elderly	Yes

Note. PRA = personal remote assistance; TAAL = trust in Ambient Assisted Living.

Regarding trust in AAL technology, results from the previous study by Steinke et al. (2014) can be partly confirmed. Perceived ease of use, as well as perceived reliability, significantly influences trust of older people. There seems to be a consistent connection between these variables in the context of AAL (H2a and H2b can be verified). The connection between perceived usefulness and trust differs from the former study as it is not significant (H2c can be rejected). The findings for the overall sample underline the statements from the senior sample. Trust is positively influenced by perceived ease of use and perceived reliability but not by perceived usefulness (see H3a to H3c). Furthermore, there is no significant influence on trust from being elderly (H3d can be rejected).

Furthermore, results underline that people using the checking operation in order to be sure the technology works correctly do not significantly differ in their evaluations of the technology from those people who do not check. This indicates that a checking operation in this experiment does not specifically address "skeptical" (e.g., low-trust) people. The senior sample shows a positive and significant correlation between starting the checking operation, in at least one scenario, and trust. In addition, there was a nonsignificant positive connection between executing the checking operation successfully in at least one scenario and trust (thus, H2d and H3e can be rejected). To further analyze the added value of a checking operation, people need to be aware that actual reliability of AAL technology may not be 100%—this will be especially analyzed in a following experiment.

In contrast to the results found in Steinke et al. (2014), intention to use does not significantly influence trust in the senior sample (H5a can be rejected). Besides, the overall sample reveals no significant influence of participants' trust in AAL technology and intention to use (H6a can be rejected). The missing significance could be the result of the relatively small sample size. Moreover, intention to use is not significantly influenced by seniority (thus, H6c can also be rejected). In accordance with the previous study, intention to use is positively influenced by perceived usefulness in the senior sample and additionally in the overall sample (H5b and H6b can be verified). Regarding the significance of seniority on perceived usefulness and perceived ease of use, it can be seen that there are opposite effects. Perceived ease of use was negatively influenced by being elderly, meaning that younger people have a higher perception of the user-friendliness of the mock-up on the tablet computer than older people (H7a can be rejected). The

perceived usefulness of the AAL technology was significantly higher in the senior sample (therefore, H7b can be verified). A qualitative evaluation of the experiment demonstrates that participants, especially those who had difficulties operating the tablet PC, avoided or aborted the checking operation. Some of them did not understand the added value of calculating mathematic tasks or how to accomplish an entire cycle. Others who started the checking operation reported that they finished the whole round correctly even if they had not. In particular, participants with higher computer experience showed a higher number of checking operations, which could also have been caused by curiosity about the camera picture. The participants were, overall, really interested in innovative technology, and some blamed themselves for the fact that they had insufficient previous experience with the tablet computer used in the experiment. Compared to the average of the older people, the intervention group had a high affinity for technology. Low usability, or a lack of usefulness, could have even greater effects in terms of trust or intention to use AAL if people had a lower affinity for technology.

In summary, the results referring to the senior sample reveal similarities, as well as differences, with the former study. Trust in AAL technology is influenced by ease of use and perceived reliability. These findings, as well as the link between perceived usefulness and intention to use, cover the conclusion from Steinke et al. (2014). According to this study, the connection between trust and intention to use AAL technology could not be proved. An interesting fact about the PRA can be found by taking a closer look at the influence on perceived ease of use, whereas trust and PRA in AAL are not directly connected. Hence, the main research question—as to whether a significant relationship exists between the type of assistance and trust of elderly persons—has to be rejected.

7. LIMITATIONS

Regarding the present experiments, some limitations should be mentioned. First, the participation was voluntary and older participants were addressed by information through flyers, telephone calls, or personal contact. Thus, the motivation for participation may have been curiosity about AAL technology or new technologies in general.

Second, 12.5% of the older participants in this sample possess a tablet computer, which shows a high technology affinity. This fact could lead to a bias in the performance of the experiment or responses to the questionnaire. In contrast to this statement, some of the older adults also reported that, despite of the introductory exercise, they did not know how to click correctly on the tablet. Moreover, the younger participants use their computer nearly 60 hr per week, which reveals a very high computer experience in the control group.

Third, due to the small number of participants in the intervention and control groups, the results of the multiple regressions, as well as those from ANOVAs, are difficult to compare. Because preparation and implementation of the experiment were very time consuming, it will be challenging to get a larger sample, which would be necessary for a more accurate analysis.

Fourth, the answers of the participants may be influenced by giving socially desirable responses. As can be seen in the study by Dunn (2009), in an interview situation, people tend to give answers that do not reflect their opinion but what they perceive to be normal. Because the participants only knew that the experiment was about innovative technologies, they might have thought that an expected answer is to be open toward new technology and rate with high values.

Fifth, due to technological restrictions, only applications from the field of households could be tested. Although the tasks seem trivial, participants had to navigate within an application, which is completely new to them. Furthermore, to gain broader and more generalizable results, applications from other fields of AAL also have to be tested.

8. FURTHER RESEARCH

To support the findings from the present, as well as previous studies regarding trust and other influencing factors on AAL technology, it would be valuable to operate further investigations. To underline the relevance of PRA for older persons, further research in the context of AAL technology should be performed. Moreover, different additional delimitations of remote support could be tested: voice calls, video and voice telephones, or remote support without a telephone. All of these technical differences in personal support could influence variables such as perceived ease of use, trust, and intention to use AAL. Experiments could also be conducted in rural areas, in which older people, who are living alone at home, could see AAL technology in a different way when compared to those living alone in larger cities.

Perceived reliability will be highlighted in the next experiment. The investigated AAL mock-up in this present study is 100% reliable, which represents the ideal case of actual reliability in technology. In a further examination, a manipulation of three different levels of reliability is undertaken. An error on the display will indicate to the participants that the action was not successful. This following study, which also analyzes the virtual home environment via a mock-up, should investigate manipulated and perceived reliability as crucial factors for the measured high-trust values in AAL. Another important survey type in connection with AAL would be a long-term study in a real-life environment of older persons. The aim of this study—trust development over time, learning effects and the performance of sensors and actors in daily use—can be examined. The handling of AAL technology by the elderly in a long-term study could be important for the design of AAL by developers and acquiring a deeper understanding of the end-user through academic research.

FUNDING

This research was supported by grants from the German Federal Ministry of Education and Research (BMBF). It is part of the project SMILEY (Smart and Independent Living for the Elderly) supported by BMBF under contract 01FC10004.

REFERENCES

Aleven, V., McLaren, B., Roll, I., & Koedinger, K. (2006). Toward meta-cognitive tutoring: A model of help seeking with a cognitive tutor. *International Journal of Artificial Intelligence and Education, 16*, 101–128.

Ambient Assisted Living Joint Programme. (2012). Catalogue of Projects 2012. Retrieved from http://www.aal-europe.eu/wp-content/uploads/2012/08/AALCatalogue2012_V7.pdf

ASIMO. (2013). Asimo, the world's most advanced humanoid robot. Retrieved from http://asimo.honda.com/inside-asimo/

Becks, T., Dehm, J., & Eberhardt, B. (2007). *Ambient Assisted Living. Neue "intelligente" Assistenzsysteme für Prävention, Homecare und Pflege*. [New "intelligent" assistant systems for prevention, home care and nursing]. Frankfurt am Main, Germany: Deutsche Gesellschaft für Biomedizinische Technik.

Becks, T., Eberhardt, B., Heusinger, S., Pongratz, S., & Stein, J. (2010). *Intelligente Heimvernetzung Komfort – Sicherheit – Energieeffizienz – Selbstbestimmung*. [Smart home networking comfort – safety – energy efficiency – self-determination]. VDE-Positionspapier. Retrieved from http://www.vde.com/de/Institut/Querschnittstechnologien/IntelligenteHeimvernetzung/Documents/Posipap-Heimvernetzung_Web[1].pdf

Bestic. (2013). Bestic Independence, inegrity, dignity & self-confidence. Retrieved from http://www.bestic.se/en/home/

Blazescape. (2012). Blazescape. Retrieved from http://www.blazescape.co.uk/facts.php

Buck, E., & Bierhoff, H.-W. (1986). Verlässlichkeit und Vertrauenswürdigkeit: Skalen zur Erfassung des Vertrauens in eine konkrete Person. [Reliability and trustworthiness: Scales for the assessment of confidence in a specific person]. *Zeitschrift für Differentielle und Diagnostische Psychologie, 7*, 205–223..

Chiriac, S., & Rosales, B. (2012). An AAL monitoring system for activity recognition. Results from the first evaluation stages. In R. Wichert & B. Eberhardt (Eds.), *Advanced technologies and societal change* (pp. 15–28). Heidelberg, Germany: Springer.

Corbin, M. (2003, May). *From online help to embedded user assistance*. Proceedings at the Society for Technical Communication's 50th Annual Conference, Dallas, TX.

Davis, F. D. (1989). Perceived usefulness, perceived ease of use, and user acceptance of information technology. *MIS Quarterly, 13*, 319–340.

Demeris, G., & Hensel, B. K. (2008). Technologies for an aging society: A systematic review of "smart home" applications. *IMIA Yearbook of Medical Informatics 2008*, 33–40.

Dijkstra, J. J., Liebrand, W. B. G., & Timminga, E. (1998). Persuasiveness of expert systems. *Behaviour & Information Technology, 17*, 155–163.

Dulude, L. (2002). Automated telephone answering systems and aging. *Behaviour & Information Technology, 21*, 171–184.

Dunn, D. S. (2009). *Research methods for social psychology*. Malden, MA: Wiley-Blackwell.

Dzindolet, M. T., Pierce, L. G., Beck, H. P., & Dawe, L. A. (2002). The perceived utility of human and automated aids in a visual detection task. *Human Factors, 44*, 79–94.

European Ambient Assisted Living Innovation Alliance. (2010). *Ambient Assisted Living Roadmap*. Amsterdam, the Netherlands: IOS Press.

Field, A., & Hole, G. (2011). *How to design and report experiments, reprinted*. Los Angeles, CA: Sage.

Fraunhofer ISST. (2013). Smart and Independent Living for the Elderly – SMILEY – Projektabschlussbericht. Retrieved from http://www.isst.fraunhofer.de/content/dam/isst/de/documents/Forschungsnews/Fraunhofer-ISST_SMILEY-Schlussbericht_1.1.pdf

Georgieff, P. (2008). *Ambient Assisted Living. Marktpotentiale IT-unterstützter Pflege für ein selbstbestimmtes Altern. FAZIT-Schriftenreihe*. [Ambient Assisted Living. Market potential of IT-assisted care for independent aging]. Stuttgart, Germany: MFG Stiftung Baden-Württemberg.

Ghazizadeh, M., Peng, Y., Lee, J. D., & Boyle, L. N. (2012, October). *Augmenting the technology acceptance model with trust: Commercial drivers' attitudes towards monitoring and feedback*. Proceedings at the 56th Annual Meeting of the Human Factors and Ergonomics Society, Boston, MA.

Giesecke, S., Hull, J., Schmidt, S., Strese, H., Weiß, C., & Baumgarten, D. (2005). *AAL - Ambient Assisted Living: Country Report Germany* [White Paper].

Grayling, T. (2002). If we build it, will they come? A usability test of two browser-based embedded help systems. *Technical Communication, 49*, 193–209.

Hinkelmann, K., & Kempthorne, O. (2007). *Design and analysis of experiments, Introduction to experimental design*. Hoboken, NJ: Wiley & Sons.

Ho, G., Wheatley, D. & Scialfa, C. T. (2005). Age differences in trust and reliance of a medication management system. *Interacting with Computers, 17*, 690–710.

Huber, L. L., Shankar, K., Caine, K., Connelly, K., Camp, L. J., Walker, B. A. & Borrero, L. (2013). How in-home technologies mediate caregiving relationships in later life. *International Journal of Human-Computer Interaction, 29*, 441–455.

Information Society Technologies Advisory Group. (1999). Orientations for Workprogramme 2000 and beyond. Retrieved from ftp://ftp.cordis.europa.eu/pub/ist/docs/istag-99-final.pdf

Ingenhoff, A. (2012). Trust in technology—An experimental comparison of elderly consumers' interpersonal trust with trust in ambient assisted living applications (Master's thesis). Munich, Germany: Technische Universität München.

Jian, J. Y., Bisantz, A. M., & Drury, C. G. (2000). Foundations for an empirically determined scale of trust in automated systems. *International Journal of Cognitive Ergonomics, 4*, 53–71.

Jonsson, A., & Bergqvist, A. (2013). *Dödsbränder i Sverige – Kvalitetsgranskning av MSB: sDödsbrandsdatabas*. [Deadly fires in Sweden - Quality review of MSB's Death Brands Database]. Karlstad, Sweden: Karlstads Universitet.

Lee, J. D., & Moray, N. (1992). Trust, control and allocation of function on humanmachine systems. *Ergonomics, 35*, 1243–1270.

Lee, J. D., & See, K. A. (2004). Trust in automation: Designing for appropriate reliance. *Human Factors, 46*, 50–80.

Lerch, F. J., Prietula, M. J., & Kulik, C. T. (1997). *The turing effect: The nature of trust in expert system advice. Expertise in context: Human and machine*. Cambridge, MA: The MIT Press.

Ma, Q., & Liu, L. (2004). The technology acceptance model: A meta-analysis of empirical findings. *Journal of Organizational and End User Computing, 16*, 59–72.

Madhavan, P., & Wiegmann, D. A. (2007). Similarities and differences between human–human and human–automation trust: an integrative review. *Theoretical Issues in Ergonomics Science, 8*, 277–301.

Masalonis, A. J., & Parasuraman, R. (1999, September). *Trust as a construct for evaluation of automated aids: Past and future theory and research*. Proceedings of the Human Factors and Ergonomics Society Annual Meeting, Houston, TX.

McKnight, H. D., Cummings, L. L., & Chervany, N. L. (1998). Initial trust formation in new organizational relationships. *The Academy of Management Review, 23*, 473–490.

Mohammed, M., Bhattacharjee, A., & Kwak, J. (2005). *U.S. Patent No. 6,973,482 B2*. Alexandria, VA: U.S. Patent and Trademark Office.

Montague, E. N. H., Kleiner, B. M., & Winchester, W. W., III. (2009). Empirically understanding trust in medical technology. *International Journal of Industrial Ergonomics, 39*, 628–634.

Muir, B. M. (1994). Trust in automation: Part I. Theoretical issues in the study of trust and human intervention in automated systems. *Ergonomics, 37*, 1905–1922.

Neyedli, H. F., Wang, L., Jamieson, G. A., & Hollands, J. G. (2010). Evaluating reliance on combat identification systems: The role of reliability feedback.

In D. H. Andrews, R. P. Herz, & M. B. Wolf (Eds.), *Human factors issues in combat identification* (pp. 249–265). Burlington, VT: Ashgate.

Osl, P., Benz, A., & Österle, H. (2010, January). *Dienstleistungen für Independent Living: Kundenanforderungen und Optionen für die Angebotsgestaltung*. [Services for Independent Living: Customer requirements and options for the supply design]. Proceedings at Ambient assisted living 2010: 3. Deutscher AAL-Kongress mit Ausstellung Assistenzsysteme im Dienste des Menschen - Zuhause und Unterwegs, Berlin, Germany.

Parasuraman, R., & Riley, V. (1997). Humans and automation: Use, misuse, disuse, abuse. *Human Factors, 39*, 230–253.

Prensky, M. (2001). Digital natives, digital immigrants, Part II: Do they really think differently? *On the Horizon, 9*(6), 1–6.

Rempel, J. K., Holmes, J. G., & Zanna, M. P. (1985). Trust in close relationships. *Journal of Personality and Social Psychology, 49*, 95–112.

Rotter, J. B. (1971). Generalized expectancies for interpersonal trust. *American Psychologist, 26*, 443–452.

Schepers, J., & Wetzels, M. (2007). A meta-analysis of the technology acceptance model: Investigating subjective norm and moderation effects. *Information & Management, 44*, 90–103.

Schneekloth, U., & Wahl, H.-W. (2005). Möglichkeiten und Grenzen selbständiger Lebensführung in privaten Haushalten (MuG III). *Repräsentativbefunde und Vertiefungsstudien zu häuslichen Pflegearrangements, Demenz und professionellen Versorgungsangeboten* (pp. 227–240). [Possibilities and limits of independent living in private households (MuG III). Representative findings and in-depth studies on home care arrangements, dementia and professional care services]. München, Germany: Bundesministerium für Familie, Senioren, Frauen und Jugend.

Sengpiel, M., & Dittberner, D. (2008). The computer literacy scale (CLS) for older adults. development and validation. In M. Herczeg, & M. C. Kindsmüller (Eds.), *Mensch und Computer 2008: Viel Mehr Interaktion* (pp. 7–16). München, Germany: Oldenbourg Verlag.

Sengpiel, M. & Wandke, H. (2010). Compensating the effects of age differences in computer literacy on the use of ticket vending machines through minimal video instruction. *Occupational Ergonomics, 9*(2), 87–98.

Statistisches Bundesamt (Destatis). (2011). Im Blickpunkt: Ältere Menschen in Deutschland und der EU. Retrieved from https://www.destatis.de/

Statistisches Bundesamt (Destatis). (2012). Alter im Wandel. Retrieved from https://www.destatis.de/

Steinke, F., Bading, N., Fritsch, T. & Simonsen, S. (2014). Factors influencing trust in Ambient Assisted Living Technology: A scenario-based analysis. *Gerontechnology*. In press.

Steinke, F., Fritsch, T., & Silbermann, L. (2012). Trust in Ambient Assisted Living (AAL)—A systematic review of trust in automation and assistance systems. *International Journal on Advances in Life Sciences, 4*(3–4), 77–88.

Stephanidis C. (2009). Designing for all in ambient intelligence environments: The interplay of user, context, and technology. *International Journal of Human–Computer Interaction, 25*, 441–454.

Stiftung Warentest. (2002). Rauchmelder: Rechtzeitig aufwachen. [Smoke Detectors: Wake up on time]. Retrieved from http://www.test.de/Rauchmelder-Rechtzeitig-aufwachen-1063379-1063408/

Streitz, N. (2010, November). *Ambient intelligence research landscapes: Introduction and overview*. Proceedings at Ambient Intelligence—First International Joint Conference, Málaga, Spain.

Struve, D., & Wandke, H. (2009). Video Modelling for training older adults to use new technologies. *ACM Transactions on Accessible Computing, 2*, 1–24.

Torres-Padrosa, V., Calle, E., Marzo, J. L., & Rovira, M. (2012, January). *Towards a mobile, assistive and intuitive videoconferencing*. Proceedings at eTELEMED 2012 – The Fourth International Conference on eHealth, Telemedicine, and Social Medicine, Valencia, Spain.

Vogel, M., & Zendler, A. (2009). Lateinische Quadrate und parameterfreie Auswertungsverfahren für die experimentelle Unterrichtsforschung. [Latin squares and parameter-free evaluation method for the experimental research on teaching]. *Notes on Educational Informatics–Section A: Concepts and Techniques, 5*, 1–12.

Weiser, M. (1991). The computer for the 21st century. *Scientific American, 265*, 94–104.

Wiegmann, D. A., Rich, A., & Zhang, H. (2001). Automated diagnostic aids: The effects of aid reliability on users' trust and reliance. *Theoretical Issues in Ergonomics Science, 2*, 352–367.

World Health Organization. (2011). Health statistics and health information systems: Definition of an older or elderly person. Retrieved from http://www.who.int/healthinfo/survey/ageingdefnolder/en/index.html

World Health Organization. (2013). Ageing and life course; What is "active ageing"? Retrieved from http://www.who.int/ageing/active_ageing/en/

Yousafzai, S. Y., Foxall, G. R., & Pallister, J. G. (2007). Technology acceptance: A meta-analysis of the TAM: Part 2. *Journal of Modelling in Management, 2*, 281–304.

Zhang, Y., & Ansarai, N. (2010). *Wireless telemedicine services over integrated IEEE 802.11/WLAN and IEEE 802.16/WiMAX Networks*. Proceedings of the IEEE Wireless Communications. Retrieved from http://web.njit.edu/~ansari/papers/10WC.pdf

Zhou, J., Rau, P.-L. P. & Salvendy, G. (2012). Use and design of handheld computers for older adults: A review and appraisal. *International Journal of Human–Computer Interaction, 28*(12), 799–826.

Ziefle, M., Himmel, S., & Wilkowska, W. (2011, November). *When your living space knows what you do. Acceptance of medical home monitoring by different technologies*. Proceedings at Information Quality in e-Health. 7th Conference of the Workgroup Human-Computer Interaction and Usability Engineering of the Austrian Computer Society, Graz, Austria.Click here to enter text.

ABOUT THE AUTHORS

Frederick Steinke is a Ph.D. candidate at the Department of Psychology at Humboldt Universität zu Berlin, Germany. His research focuses on elderly people's trust, perceived ease of use and intention to use Ambient Assisted Living. Moreover, he examines elderly social networking activities in connection with home automation and assistive technology.

Alexander Ingenhoff studied business administration at Universität Duisburg-Essen and holds a Master's in Consumer Affairs from Technische Universität München, Germany. One focus of his academic research is consumer behavior—including the elderly's adoption of new technologies. Today, he works for an international strategy consultancy as a researcher in the consumer goods and retail industry.

Tobias Fritsch, Ph.D., completed his doctoral thesis in Computer Science at Freie Universität Berlin, Germany. Currently he is at Ruprecht-Karls-Universität Heidelberg, Germany, and the main emphasis of his research concentrates on social networking activities with a specific focus on the integration of the elderly population.

RESEARCH ARTICLE 4

Steinke, F., Hertzer, A., & Fritsch, T. (2014). Experimental manipulation of reliability in ambient assisted living – an analysis of trust and intention to use. *International Journal of Human Factors and Ergonomics, 3(2)*, 122-147.

Experimental manipulation of reliability in ambient assisted living – an analysis of trust and intention to use

Frederick Steinke*

Humboldt Universität zu Berlin,
Rudower Chaussee 18,
12489 Berlin, Germany
Email: steinkef@student.hu-berlin.de
*Corresponding author

Andreas Hertzer

Universität Augsburg,
Universitätsstr. 2,
86159 Augsburg, Germany
Email: andreashertzer@web.de

Tobias Fritsch

Universität Heidelberg,
Grabengasse 1,
69117 Heidelberg, Germany
Email: t.fritsch@gmx.net

Abstract: The present study examined three different reliability levels of an ambient assisted living (AAL) application and its influence on trust and intention to use. Past research has generally supported differences in trust in automation by a variation of reliability. However, investigations in the context of AAL, with older people as a target group, have not been empirically established. A 3 reliability (100%; 90%; 80%) × 2 target group (older people; students) experimental design was used for solving home automation tasks with an AAL mock-up. The study revealed no significant influence on trust in AAL and intention to use by the three different reliability conditions. In contrast, older people's perceived reliability had a significant impact on both variables. The study highlighted the importance of perceived reliability in trust in AAL and usage intention, whereas the manipulated reliability showed only tendencies of these connections.

Keywords: ambient assisted living; AAL; assistive technology; automation; intention to use; older people; perceived ease of use; perceived usefulness; reliability; technology; trust; human factors; ergonomics.

Reference to this paper should be made as follows: Steinke, F., Hertzer, A. and Fritsch, T. (2014) 'Experimental manipulation of reliability in ambient assisted living – an analysis of trust and intention to use', *Int. J. Human Factors and Ergonomics*, Vol. 3, No. 2, pp.122–147.

Biographical notes: Frederick Steinke received his degree as a Diplom-Kaufmann at Freie Universität Berlin. He is a PhD candidate at the Department of Psychology at Humboldt Universität zu Berlin, Germany. His research focuses on elderly people's trust, perceived ease of use and intention to use ambient assisted living (AAL). Moreover, he examines elderly social networking activities in connection with home automation and assistive technology. In his field of research, he published several papers on AAL technology. Currently, he works as Head of Group CIO Office at Allianz SE where he is involved in several strategic IT projects.

Andreas Hertzer studied information-oriented business administration, in the cluster finance and information, at the University of Augsburg and graduated successfully with the degree of Diplom-Kaufmann. In this area, he focused on the interface between the pure business administration and computer science. Here, he learned the theoretical basics in the analysis of business processes in order to improve this to sustainably efficient processes to model and implement. This knowledge he has already applied in some internships in an IT consulting and an insurance company.

Tobias Fritsch completed his first master and respective doctoral thesis in computer science at the Freie Universität Berlin. He furthermore completed various other masters and a PhD as well as an executive MBA. In his professional career, he worked for a large senior management strategic consulting company, before taking various leadership positions within the Allianz. Currently, he is working as the programme executive in the Data Center Consolidation programme. His scientific work is focusing on the adaption of new technology in the customer interaction, ranging from entertainment products up to business models and social network analysis.

1 Introduction

Automation in daily life supports people in various fields such as home automation in the household (Paulus et al., 2009; Floeck and Litz, 2008). In contrast to applications in aviation or shipping, which are operated exclusively by professionals, technologies in the living environment can be used by anyone. Older people, though, have less experience with these innovative technological devices. The present study places particular focus on ambient assisted living (AAL) technologies. AAL "refers to intelligent systems of assistance for a better, healthier and safer life in the preferred living environment and covers concepts, products and services that interlink and improve new technologies and the social environment" [AALIANCE, (2010), p.6]. AAL technologies encompass such devices as floor sensors that identify emergency situations (Belbachir et al., 2012) to social media solutions with the intention of supporting and facilitating participation in social life (Elder-Spaces, 2011).

In recent years, many AAL research projects have been carried out with the support of private funding by participating organisations on the one hand and public funding from the European Commission and AAL Partner States on the other (Ambient Assisted Living Joint Programme, 2013). From 2008 until 2013, the planned budget for the Ambient Assisted Living Joint Programme (2013) was €700 million – financed by 50% public and 50% private funding. Nevertheless, few AAL solutions have gone beyond the prototype stage. Barriers that prevent a rapid market launch can be found in missing

standards or interoperability (VDE, 2009). Additionally, awareness in the target group of older people, as well as acceptance and subsequent use of the existing products, is low (Grauel and Spellerberg, 2008), but the potential has been detected (BITKOM, 2009). Since older people are more likely to become dependent on such technologies in the future, this target group will be analysed in more detail.

Due to demographic shifts, the number of elderly people has increased in many countries (UNDESA, 2010). During 2005 to 2010, the globally annual growth rate of the elderly accounted for 2.6% and surpassed the overall population's growth rate of 1.2% per annum. An increase from 784 million people above 60 years of age in 2011 to two billion people in 2050 is predicted. Moreover, the number of people aged 80 years or over is predicted to grow from 109 million to 402 million in the same period (UNDESA, 2010). With 21%, Germany has the highest percentage of people aged 65 years and over within the European Union. A long-term forecast shows that by 2060, assuming a simultaneous decrease of the total population, 34% of the population will be aged 65 or over, and 9% of the population will be aged 85 or over. In 2009, the corresponding figures were 21% and 2%, respectively (Destatis, 2011).

Moreover, considering the ageing population, an increase in long-term care is predicted. In 2007, 5% of people aged between 70 and 74 years, and 62% of people aged 90 years and above, were in need of care in Germany. Remaining in the family home for as long as possible is the preferred alternative for people who need care. They prefer assistance from outpatient services in their own surroundings in order to delay, or avoid, a move to a residential care facility. In 2007, 68% of people who needed care were given this provision at home (Statistische Ämter des Bundes und der Länder, 2010). Since demographic changes have caused shortages in social security funds and an unequal distribution of nursing staff for people who require care (Afentakis and Maier, 2010), AAL, as an overall system, could provide support within the healthcare industry.

The front end of AAL technology is designed to be as easy as possible to handle. Furthermore, the technical details of AAL, as well as the interfaces to various service providers, are hidden and not obvious for the end-user due to the high complexity. Thus, placing trust in automation plays an important role since people will not understand all automation in detail. In the case of AAL, the interaction between technology and the service provider is significant for the life of the end-user, whereby trust could be an important factor for usage in general. As seen in Lee and Moray (1992, 1994), the usage can be positively influenced by personal trust in this automation. In contrast, the factor of over-reliance (Parasuraman and Riley, 1997), as a consequence of incorrect calibration, can lead to tragic accidents – for example, in the field of passenger transport systems (National Transportation Safety Board, 1997; Parasuraman and Miller, 2004).

Trust can be defined as "the attitude that an agent will help to achieve an individual's goals in a situation characterized by uncertainty and vulnerability" [Lee and See, (2004), p.51]. Former studies of trust in automation contain a wide research spectrum – for example, in the following areas: automotive (see e.g., Abe and Richardson, 2006; Kantowitz et al., 1997; Lees and Lee, 2007; Stanton and Young, 2005), aviation (see e.g., Bliss and Dunn, 2000; Hughes et al., 2009; Keller and Rice, 2010; McGuirl and Sarter, 2006; Wickens et al., 2009), combat identification (see e.g., Dzindolet et al., 2002; Rice, 2009; Wang et al., 2009; Yeh and Wickens, 2011) or others (see e.g., Ezer et al., 2008; Moray et al., 2000; Parasuraman and Wickens, 2008). A more detailed literature overview can be found in Steinke et al. (2012b).

This study also revealed that, as yet, there are no explicit research activities regarding trust in AAL technology (Steinke et al., 2012b). Further studies by the authors showed noteworthy results which build the basis for the current study. Regarding the location of the sensors used within an AAL solution, Steinke et al. (2012a) revealed that AAL sensors which are permanently attached in the accommodation are considered as more reliable than sensors attached to clothing or on the body. Additionally, those elderly living in single households showed lower trust values in AAL sensors, in general, than people living with others (Steinke et al., 2012a). Consequent scenario-based studies focussed on sensor and actor technology fixed in the accommodation. A questionnaire study with 292 persons (mean age = 74.39 years) revealed a strong relationship between trust in AAL and the intention to use AAL (Steinke et al., 2014a). The authors worked out that expected reliability, perceived ease of use and perceived usefulness of AAL significantly influence trust in AAL on the one hand, and the variables of information procurement, interest in technology and perceived health status directly influence the end-user intention to use on the other. The differentiation within the study between people with and without the need for care showed lower values for trust and intention to use in the group of people with need for care. Moreover, the survey revealed that younger participants, as well as those with a better perceived health status, have higher trust values and more intention to use AAL (Steinke et al., 2014a).

A further study by Steinke et al. (2014b) differentiated, in an experimental setting, between support in an AAL mock-up by personal remote assistance and embedded technical assistance. The analysis showed that older participants who are supported by a personal operator via remote assistance solve a significantly greater number of tasks than people with technical support alone. Additionally, personal remote assistance significantly influenced older people's perceived ease of use of the AAL technology. The results showed no significant correlation between the type of assistance and older people's trust and intention to use AAL. A significant connection between trust in AAL technology and perceived ease of use, as well as perceived reliability, was also detected (Steinke et al., 2014b). These results – in terms of trust, intention to use and (perceived) reliability – will be analysed in the current study in more detail. In critical situations especially, the person in need has to rely on AAL's functionality and the reliability of the technology. For example, in the case of a person collapsing, errors resulting from imperfect technology can have serious consequences. Reliability can be defined as "the ability of an item to perform a required function under stated conditions for a stated period of time" [Naresky, (1970), p.199].

In the context of reliability, engineering reliability can be defined as "the probability that a product will operate or a service will be provided properly for a specified period of time […] under the design operating conditions […] without failure" [Elsayed, (2012), p.3]. Due to the different fields of AAL applications, reliability in AAL technology has diverse facets. The technical components (as well as the service provider) connected with the technology can produce errors. The present study excludes human errors and focuses solely on automation errors. Within automation studies, a distinction is made between perfect (without any error) and imperfect automation, whereas imperfection can be defined differently. In different studies in which reliability was considered amongst others as an influential factor for trust in automation, imperfect automation with an error rate up to 40% was used (e.g., Dixon and Wickens, 2006). In some of the studies,

participants are informed of the fact that the technology is capable of errors (Ezer et al., 2008; Rovira et al., 2007). Moreover, a framework by Dzindolet et al. (2001) predicted that trust is based on the result of a match between perceived reliability of manual control and perceived reliability of the automation. A differentiation between miss and false alarm as feedback was used as another criterion for reliability investigations (e.g., Madhavan et al., 2006; Wickens and Colcombe, 2007). This distinction is not considered in the present study and therefore not described in detail.

These studies focussed on human-machine interaction in the context of automation, whereas in the context of AAL no human control of sensors and actors is possible. People can operate AAL functions via an interface on a tablet computer or smartphone but have no access to manual handling of the underlying technology in the home environment. Given that people who are assigned for use of AAL often have physical or mental impairments, even the handling of the device can be seen as challenge for the end-user. The previously mentioned studies in the context of AAL technology (Steinke et al., 2014a, 2014b) showed that higher expected/perceived reliability can be seen as an indicator for higher trust in AAL. As detailed in the following sections, the present study differentiated between three reliability levels which are manipulated experimentally. The change of reliability during the experiment may affect trust in automation (Wiegmann et al., 2001). To follow the thread, this article is aligned to the following research question:

- How do the different reliability levels of an AAL application influence end-users' trust and intention to use?

2 Methodology

2.1 Participants

The present laboratory experiment (N = 60) contains a between-group design with 30 older (mean age = 70.80 years, SD = 7.18, range = 61 to 85 years), as well as 30 younger participants aged between 20 and 29 years (mean age = 24.33 years, SD = 2.41). All sample details can be found in Table 1.

Table 1 Descriptive statistic total sample (N = 60) including computer experience

	Senior sample (n = 30)			*Junior sample (n = 30)*		
	Reliability level			*Reliability level*		
	100%	*90%*	*80%*	*100%*	*90%*	*80%*
# of participants						
Total	*10*	*10*	*10*	*10*	*10*	*10*
Male	5	6	6	5	6	5
Female	5	4	4	5	4	5
Age [mean]						
Total	*70.2*	*70.7*	*71.5*	*24.7*	*23.5*	*24.8*
Male	69.2	70.5	71.67	24.4	23.5	24.8
Female	71.2	71	71.25	25	23.5	24.8

Table 1 Descriptive statistic total sample (N = 60) including computer experience (continued)

	Senior sample (n = 30)			*Junior sample (n = 30)*		
	Reliability level			*Reliability level*		
	100%	*90%*	*80%*	*100%*	*90%*	*80%*
# people living alone						
Total	*1*	*4*	*1*	*1*	*0*	*0*
Male	0	2	1	1	0	0
Female	1	2	0	0	0	0
# of user [computer]						
Total	*7*	*8*	*7*	*10*	*10*	*10*
Male	4	6	4	5	6	5
Female	3	2	3	5	4	5
Years of computer ownership [mean]						
Total	*18.29*	*19.25*	*16.14*	*13.3*	*14.2*	*13.4*
Male	18.25	19.33	21	12.8	14	14.2
Female	18.33	19	9.67	13.8	14.5	12.6
Use of computer [mean h/week]						
Total	*10.13*	*11.31*	*19.5*	*27.5*	*32.3*	*49.2*
Male	19.25	11.08	33	22	36.67	54.4
Female	1.33	12	1.5	33	25.75	44
# of user [tablet computer]						
Total	*1*	*0*	*0*	*4*	*2*	*3*
Male	0	0	0	2	1	2
Female	1	0	0	2	1	1

The younger control group allows us to compare age differences in terms of trust, as well as to ensure comparability to the previous study in which this design was also chosen to analyse the two different age groups – students as a younger control group and older participants (Steinke et al., 2012a). The control and experimental groups are randomly distributed to three experimental scenarios each. These three scenarios differ by the reliability condition of either 80%, 90% or perfect (100%) reliability of the AAL application. In the run-up to this experiment, two preliminary studies – with five younger participants (mean age = 25.43 years, SD = 3.02) in a first study, as well as five older participants (mean age = 67.98 years, SD = 4.35) in a second study – were conducted. Based on these preliminary studies, the design of the mock-up and the task description was slightly modified.

2.2 Equipment

The participants will have to use a mock-up of an AAL application, which was modelled after an AAL prototype from the research project 'Smart and Independent Living for the Elderly' (SMILEY) (Fraunhofer ISST, 2013). The experiment was conducted using a tablet computer by Fujitsu – the Stylistic Q550, 1.70 GHz, 2.00 GB RAM, 10.1 inch with a resolution of 1,280 × 800. The operating system was Windows 7 and the tablet was operated via touch screen.

2.3 Experimental design

Based on variables of the technology acceptance model (TAM) (Davis, 1989), the questionnaire designed by Steinke et al. (2014a) was used as an initial point. The additional item 'general trust' (T_{gen}) was added and measured before performing the experiment. In contrast, trust in AAL (T_{AAL}) was measured after the experiment. Both items were derived from the scale by Jian et al. (2000). Following the process of the experimental tasks, the participants are also asked about perception regarding ease of use (PEOU), usefulness (PU), and reliability (PR), as well as their usage intention (IU). All of these variables are measured on a seven-point Likert scale subsequent to the experiment. Further behavioural data, such as the investment to fulfil the tasks, the number of clicks and usage of the checking operation, which were implemented for the participants as a control function to prove if the action was executed correctly by the AAL system, were raised during the experiment. In total, six variables (T_{gen}, T_{AAL}, PEOU, PU, PR, IU) were measured by the questionnaire and four (reliability level, number of clicks, investment of time, number of checking operations) within the experiment. In addition, demographic data and (tablet) computer possession and usage were taken anonymously. Table 2 shows the questionnaire presented in German.

Table 2 Questionnaire used in this study (in German)

Trust in technology
Ich glaube, dass die meisten Technologien das tun, für was sie entwickelt wurden. (I believe that most technologies do, for what they were developed.)
Eine große Mehrheit der Technologien sind hervorragend. (A large majority of technologies are excellent.)
Die meisten Technologien haben die Eigenschaften, die für ihre Aufgaben benötigt werden. (Most technologies have the functions which are required for their tasks.)
Ich denke, die meisten Technologien ermöglichen es mir zu tun, was ich tun möchte. (I think most technologies enable me to do what I want to do.)
Meine typische Vorgehensweise ist es neuen Technologien zu vertrauen, bis sie mir das Gegenteil beweisen. (My typical approach is to rely on new technologies until they prove me wrong.)
Wenn ich eine Technologie zum ersten Mal verwende, gehe ich davon aus, dass sie funktioniert. (When I use a technology for the first time, I assume that it will work.)
Normalerweise vertraue ich einer Technologie, bis sie mir einen Grund gibt, nicht mehr zu vertrauen. (Usually, I trust a technology until it gives me a reason not to trust.)
Trust in AAL (T_{AAL})
Die Unterstützungstechnik erscheint mir trügerisch. (The assistive technology appear deceptive to me.)
Ich vertraue darauf, dass mir die Unterstützungstechnik Sicherheit bietet. (I trust that the assistive technology provides security to me.)
Ich bin gegenüber der Unterstützungstechnik misstrauisch. (I am wary of the assistive technology.)

Notes: English version in parentheses. These are the scales that were collected as part of the questionnaire. Questions about sociographic factors (e.g., about use of computers) were also included. The response format was a scale from '---' (strongly disagree) to '+++' (totally agree).

Table 2 Questionnaire used in this study (in German) (continued)

Trust in AAL (T_{AAL})
Ich vertraue der Unterstützungstechnik. (I rely in the assistive technology.)
Ich misstraue den Absichten, Handlungen oder Folgen der Unterstützungstechnik. (I am suspicious of the intentions, actions or consequences of the assistive technology.)
Die Aktivitäten der Unterstützungstechnik haben eine schädliche oder schädigende Folge. (The activities of the assistive technology will have a harmful or injurious outcome.)
Ich vertraue auf die Unterstützungstechnik. (I trust in the assistive technology.)
Perceived ease of use (PEOU)
Die Unterstützungstechnik zu verwenden verwirrt mich. (Using the assistive technology confuse me.)
Bei der Anwendung der Unterstützungstechnik mache ich häufig Fehler. (While using the assistive technology I often make erorrs.)
Der Umgang mit der Unterstützungstechnik frustriert mich. (Handling of the assistive technology is frustrating.)
Der Umgang mit der Unterstützungstechnik erfordert eine Menge meiner geistigen Anstrengung. (Interacting with the assistive technology requires a lot of my mental effort.)
Die Verwendung der Unterstützungstechnik finde ich umständlich. (Using the assistive technology is cumbersoming.)
Insgesamt finde ich die Unterstützungstechnik einfach zu bedienen. (Overall, I think that the assistive technology is easy to use.)
Perceived usefulness (PU)
Die Unterstützungstechnik verbessert die Qualität des Wohnens im eigenen Haushalt. (The assistive technology improves the quality of living in my own household.)
Ich empfinde es als komfortabel, von der Unterstützungstechnik im häuslichen Umfeld unterstütz zu werden. (I find it convenient to be supported by the assistive technology in my home environment.)
Die Unterstützungstechnik unterstützt das Leben in meinem eigenen Haushalt. (The assistive technology supports living in my own household.)
Die Unterstützungstechnik ermöglicht mir, länger in meinem eigenen Haushalt zu leben, als dies sonst möglich wäre. (The assistive technology allows me to live longer in my own household than I would otherwise be able to.)
Der Besitz der Unterstützungstechnik erhöht mein Ansehen in meinem Umfeld. (The possession of the assistive technology increases my reputation in my environment.)
Die Unterstützungstechnik macht es mir einfacher, länger in meinem eigenen Haushalt zu leben. (The assistive technology makes it easier to extend living in my own household.)
Insgesamt finde ich die Unterstützungstechnik in meinem eigenen Haushalt sinnvoll. (Overall, I consider having the assistive technology in my own household as useful.)

Notes: English version in parentheses. These are the scales that were collected as part of the questionnaire. Questions about sociographic factors (e.g., about use of computers) were also included. The response format was a scale from '---' (strongly disagree) to '+++' (totally agree).

Table 2 Questionnaire used in this study (in German) (continued)

Perceived reliability (PR)
Die Unterstützungstechnik erscheint mir zuverlässig. (The assistive technology appears to be reliable.)
Die Unterstützungstechnik erscheint mir präzise. (The assistive technology appears to be precise.)
Die Unterstützungstechnik erscheint mir sicher. (The assistive technology appears to be safe.)
Die Unterstützungstechnik erscheint mir ehrlich. (The assistive technology appears to be honest.)
Ich denke, die Unterstützungstechnik arbeitet fehlerfrei. (I think the assistive technology will work correctly.)
Die Unterstützungstechnik weist für mich Zuverlässigkeit auf. (The assistive technology shows reliability for me.)
Usage intention (IU)
Es ist wahrscheinlich, dass ich die Technologie verwenden würde. (It is probably that I would use the technology.)
Ich würde auf jeden Fall einmal ausprobieren, die Technologie zu nutzen. (I would at least try to use the technology.)
Sobald die Möglichkeit besteht, würde ich die Technologie nutzen. (As soon as the opportunity arises, I would use the technology.)

Notes: English version in parentheses. These are the scales that were collected as part of the questionnaire. Questions about sociographic factors (e.g., about use of computers) were also included. The response format was a scale from '---' (strongly disagree) to '+++' (totally agree).

Within this experiment, an examination of three different manipulated reliability levels is included. The manipulated reliability levels set for this experiment are deduced from the results of an online questionnaire with 206 participants (mean = 38.0 years, range = 14 to 88 years) (Steinke et al., 2013). Within this study, the users' expected reliability of different daily-life technologies, such as dishwashers, computers and navigation systems, was investigated and compared to the expected reliability of three AAL functions: 'stove', 'floor sensor' and 'window'. Due to the results provided by Steinke et al. (2013), which have shown an overall value of about 95% of expected reliability in the segment of AAL technology, a demarcation in one experimental setting with perfect automation and two settings with imperfect automation (90% and 80% manipulated reliability) were used in the present study.

2.4 Procedure

Each participant solved 30 tasks within a virtual accommodation by using a mock-up of an AAL system – either in the 80%, 90% or 100% reliability condition. The design of the mock-up was derived from a previous experiment investigating two types of assistance – personal remote and embedded technical assistance for AAL technology (Steinke et al., 2014b). In the present study, the control of devices in the home environment is also simulated via an application on a tablet computer.

Based on this application, the participants undertook 30 tasks within seven consecutive rooms. The order of the tasks was fixed so that all participants in the three reliability conditions had to perform the tasks in the same sequence. The participants were asked to control the status – for example, of the stove – and subsequently turn off the stove. They were also asked to control and close the windows in different rooms – such as the kitchen or living room – and to reduce the temperature of the heating [for more details see Hertzer (2013), all actions can be found in Appendix]. All these tasks that the participants are asked to solve are performed via remote control on the tablet. Due to the fact that the application is still in the prototype phase, the application itself was not performing any tasks in reality – only in the virtual surroundings.

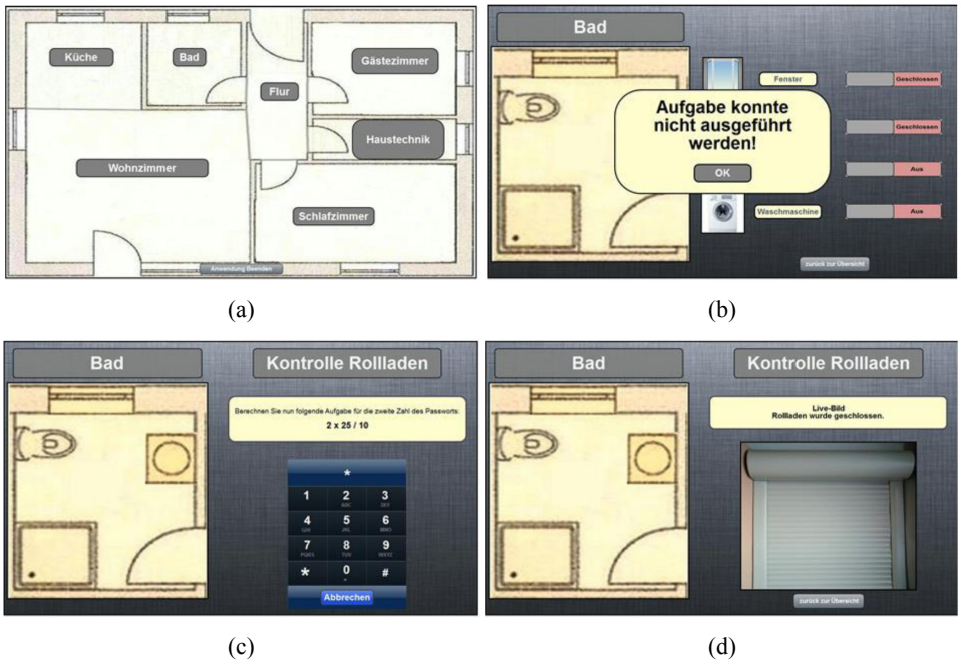
Each participant completed only one out of the three reliability conditions. The first group completed an experiment with perfect automation, which means that no errors occurred during the solving of the problems. The second experimental group experienced 90% manipulated reliability, which means that within the 30 tasks three errors occurred. An error in understanding of the experiment is, for example, an open blind after the participant had performed the action 'closing the blind'. All errors are shown on the surface of the mock-up displayed by an error message to the user, which stated that the operation could not be performed successfully. In contrast to previous studies in which the user got wrong or no error messages (Madhavan et al., 2006; Wickens and Colcombe, 2007), in the present experiment the participant received – in any case – a correct error message if the action was not performed completely. The participant had the opportunity to execute this single task a second time. At the second attempt, if the participant performed the task correctly, no error message occurred – this task was finished. Following this logic, the mock-up of the third experimental group had a modelled manipulated reliability of 80%, which means that six errors occurred within this condition.

The time duration to fulfil all tasks was not limited. The investment of time as well as the number of clicks was measured from the first task in the hall until the participant had finished all 30 tasks. To provide the best possible comparability, the number of additional clicks per participant was taken, which means that the number of minimal clicks per condition, as well as the amount of clicks for the usage of the checking operation, was subtracted to identify the participants' clicks which were not necessary for solving the tasks. The number of minimum clicks used to solve all 30 tasks in one of the different experimental conditions was: 50 clicks in the 100% reliability condition, 56 clicks in the 90% condition and 62 clicks in the 80% condition.

Within the instructions of the experiment, the participants received no information about the reliability of the AAL application and whether errors occur or not. Analogous to the former experiment by Steinke et al. (2014b), participants have the possibility to check the correct functionality of the AAL technology via a 'checking operation'. By monitoring the state of the performance – for example, a camera view of the blind after having it closed by the system – the participant is given the opportunity to check the system reliability of the sensors and actors – after finishing all tasks within a room by solving arithmetical tasks. As all participants had to perform 30 tasks during the experiment, there was a maximum of 30 opportunities to check the AAL system reliability. These clicks for the checking operation also have to be subtracted from the overall number of clicks. Depending on the successful execution of the checking operation, the maximum number of clicks subtracted per experimental task is six.

To prevent this function being used every time, beside the fact that the participant has doubts with regard to the correct functionality or not, arithmetical tasks are implemented as hurdles (Ho et al., 2005). These tasks include the four basic calculating methods with response options from one to nine. This artificial barrier consists of calculating tasks which are displayed on the screen and work like a transaction authentication number (TAN) for online banking. To receive the camera view of the respective technology, the participant has to solve four different calculation tasks per item. If the arithmetical tasks were not solved correctly, the camera view was not shown. Also, for this operation no time limit was given. Figure 1 shows screenshots of the experimental mock-up.

Figure 1 Screenshots from the AAL mock-up, (a) layout of the accommodation (b) error message 'task could not be performed' of one task in the bathroom (c) view of one arithmetical task and the keypad for entering numbers within the checking operation 'blind' in the bathroom (d) camera view to check the blind in the bathroom (see online version for colours)



(a) (b)

(c) (d)

2.5 Hypotheses

Both of the following hypotheses have been set up in order to analyse the impact of the variation of reliability of the described AAL application as well as to evaluate the former mentioned variables with respect to trust and the intention to use.

H1 Trust in AAL is negatively influenced by

- a number of clicks
- b investment of time
- c number of checking operations.

Trust in AAL is positively influenced by

d higher reliability level

e general trust in technology

f perceived reliability

g perceived ease of use

h perceived usefulness.

H2 Intention to use is negatively influenced by

a number of clicks

b investment of time.

It is positively influenced by

c higher reliability level

d trust in AAL

e perceived reliability

f perceived ease of use

g perceived usefulness.

3 Results

As described in the experimental design, the present study combines measurement and analysis of variables during the experiment and those obtained by questionnaire. Behavioural data such as the number of clicks and investment of time for each reliability level, as well as usage of the checking operation. Following this, the outcomes obtained from the questionnaire study were examined. For detailed analysis, the data was evaluated on the basis of descriptive and inferential statistics. The data analysis was conducted by using SPSS 21.

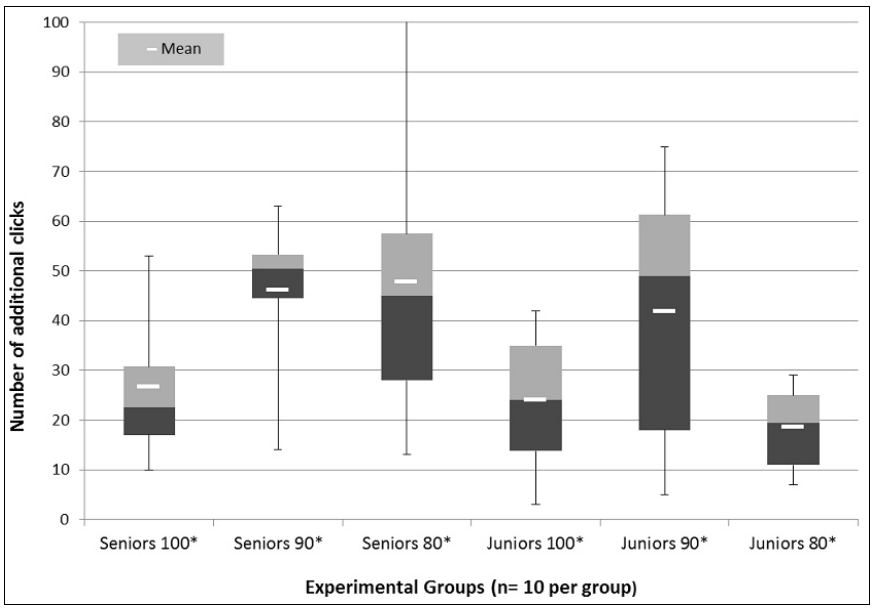
3.1 Number of clicks and investment of time

The number of clicks as the first behavioural indicator was measured for each participant during the experiment. For an aggregated analysis, the results are divided into the senior experimental and junior control groups and additionally split into the three different reliability conditions per group. Figure 2 visualises the additional number of clicks within these six experimental groups by means of box-plots. The present box-plots show the mean values and median, as well as the first and the third quartile and whiskers for all groups.

Following this evaluation, the lowest additional click rate was observed for the 100% reliability condition in the senior group (mean = 26.6 clicks). Seniors clicked more often in the 90% (mean = 46.1) and 80% (mean = 47.7) conditions. In order to statistically test for differences in means between groups a one-sided Bonferroni post hoc test was performed. This test was chosen over a simple t-test, since it avoids alpha error inflation that occurs when a row of t-tests is used to compare means between several groups. In addition, the Bonferroni post hoc test is a very conservative post hoc test and thus enhances the accuracy of the results. The increase of additional clicks from the 100%

reliability treatment to the 80% reliability treatment is marginally significant at the 10% level in the senior group. However, the difference in additional clicks between the 100% and the 90% reliability treatment is not statistically significant in the senior group. Juniors reached their lowest value in the 80% condition (mean = 18.5) followed by the 100% condition (mean = 23.9) and a substantial rise in the 90% reliability condition (mean = 41.8). Performing a one-sided Bonferroni post hoc test revealed that the number of additional clicks is significantly higher in the 90% reliability treatment compared to the 80% reliability treatment (at the 5% level) and to the 100% reliability treatment (at the 10% level) in the junior sample. Furthermore, the biggest click span can be seen in the senior 80% and junior 90% conditions, which are also the two conditions with the highest additional numbers of clicks (and one outlier with 114 additional clicks in the senior 80% reliability condition). Aggregated over all reliability treatments, the juniors performed significantly less additional clicks than the seniors. This was tested with a one-sided t-test of equal variances and is statistically significant at the 5% level.

Figure 2 Box-plot diagram: number of additional clicks among the different experimental groups



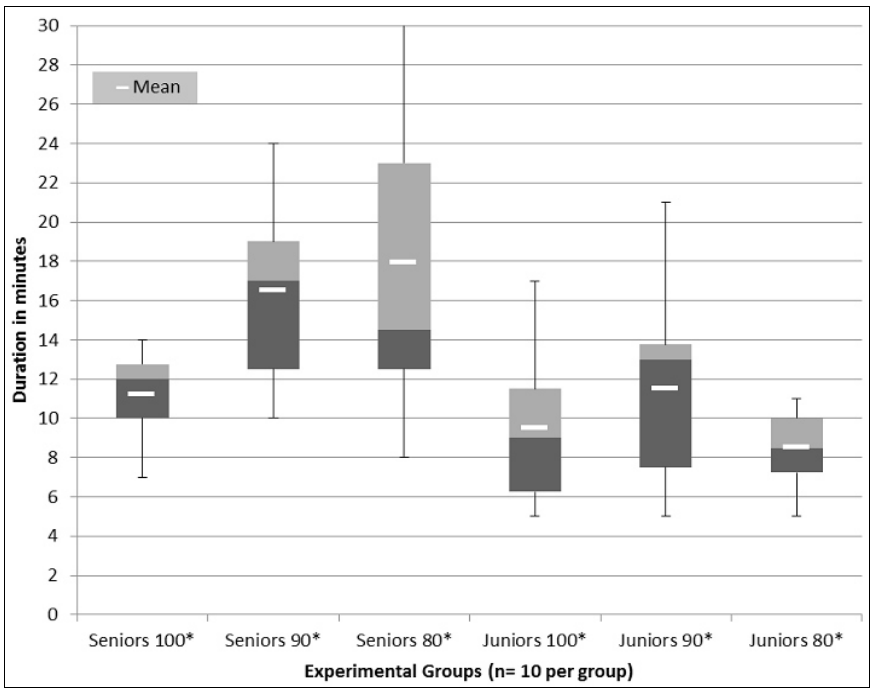
Note: *Numbers describe the reliability level (e.g., 'Seniors 100' is the senior sample in the 100% reliability condition).

Source: Authors' design

In addition to the number of clicks, the investment of time for completing the experiment by all participants was measured and clustered per experimental condition in both age groups. In the senior sample, a decrease in the system's reliability level led to an increased time to perform all tasks in the current experiment. In detail, participants in the conditions of imperfect automation needed more time to perform the experimental tasks (mean = 17 m 54 s in the 80% condition; mean = 16 m 30 s in the 90% condition) than participants with perfect automation (and a mean value of 11 m 12 s). However, these differences are not statistically significant when tested with a one-sided Bonferroni post hoc test. Moreover, the younger participants were significantly faster in solving the

30 tasks of the experiment than the senior experimental group. This was tested with a one-sided t-test of unequal variances and is statistically significant at the 1% level. As can be seen in Figure 3, the 80% junior group required the least time with a mean of 8m30s, followed by the 100% condition with a mean value of 9 m 24 s. A peak can be seen in the 90% control group with 11 m 24 s, which accompanied the higher number of additional clicks for solving all tasks in this sub-sample.

Figure 3 Box-plot diagram: investment of time for completing all experimental tasks



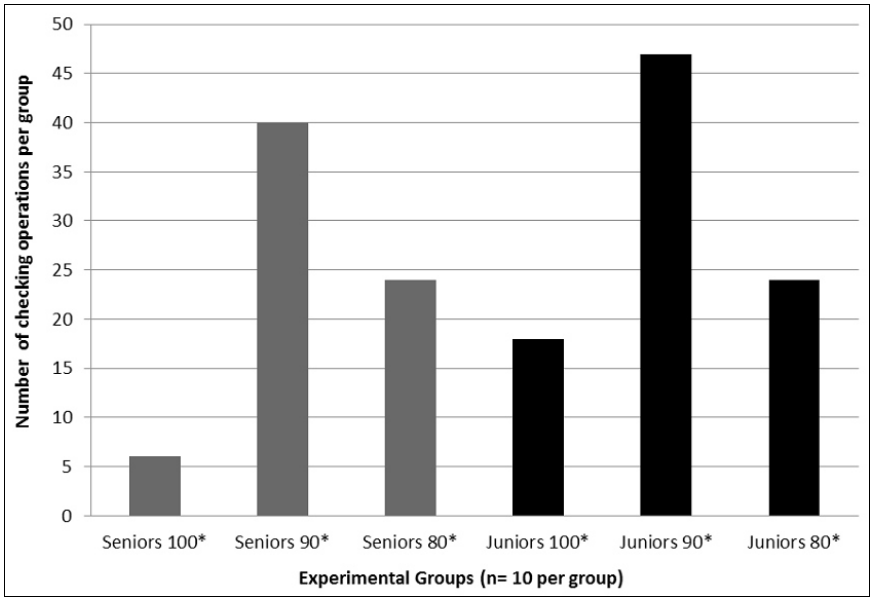
Note: *Numbers describe the reliability level (e.g., 'Seniors 100' is the senior sample in the 100% reliability condition).

Source: Authors' design

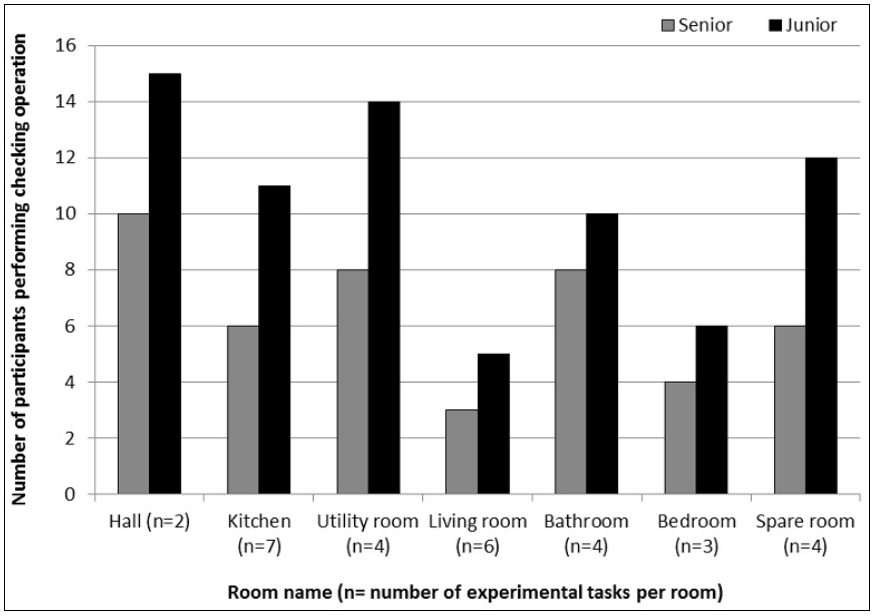
3.2 Checking operation

Figure 4 displays the total number of executed checking operations divided into the six experimental groups. In total, 70 checking operations by the seniors, and 89 checking operations by the younger participants, were executed by the 30 participants per age group. As can be seen in Figure 4(a), there were six checking operations by seniors in the 100% reliability condition, 40 checking operations within the 90% condition and 24 checking operations in the 80% condition were performed. In contrast, in the junior control group, there were 18 checking operations in the 100% condition, 47 in the 90% condition and 24 in the 80% condition. In both age groups, participants in the experimental condition with perfect automation used the checking operation to control the system reliability least, and in the 90% condition used it most frequently. A univariate ANOVA with the amount of checking operations as a dependent variable showed no statistically significant differences between the reliability conditions.

Figure 4 (a) Total number of checking operations divided by experimental groups (b) Number of participants performing the checking operation divided by rooms (in chronological sequence)



(a)



(b)

Note: *Numbers describe the reliability level (e.g., 'Seniors 100' is the senior sample in the 100% reliability condition).

Source: Authors' design

Figure 4(b) revealed the number of participants using the checking operation in the different rooms (arranged in chronological order). As the 30 tasks are not equally distributed over the seven rooms, the absolute number is presented in combination with the room names. As can be seen, in all rooms the younger participants used the checking operation more often. Furthermore, in the living room the fewest participants used the opportunity to check the system reliability. Despite the facts – that in the hall, on the one hand, the lowest number of tasks existed (n = 2), while on the other hand, it was the only room in which no automation error occurred – in both groups, most participants used the checking operation in this room.

3.3 Questionnaire data

In addition to the evaluation of the behavioural data, the questionnaire by Steinke et al. (2014a) was used in a slightly modified version to measure the former introduced variables. In the present section, the questionnaire data which were collected as part of the experiment are analysed. Several analyses of variances were conducted in order to test for deviations in different conditions evoked by the systematic variation of reliability. Therefore, a univariate ANOVA with T_{AAL}, perception regarding ease of use (PEOU), usefulness (PU), reliability (PR), as well as usage intention (IU), used as dependent variables, was performed. As a result, no differences between the various conditions were found. Furthermore, the correlation between T_{gen} and T_{AAL} is significant ($r = .65$, $p < .01$), whereas regarding the amount of checking operations, there is no significant correlation with T_{AAL} ($r = .03$, $p > .05$). The correlation between investment of time and T_{AAL} is also statistically insignificant ($r = .23$, $p > .05$). Moreover, there is no statistically significant correlation between IU and investment of time ($r = .16$, $p > .05$) or between IU and the number of checking operations ($r = .09$ $p > .05$). For this reason, these measures were ignored in the subsequent analysis of IU and T_{AAL}.

An examination of the explained variance of T_{AAL} and the impact on IU was conducted by two linear regressions. A stepwise regression is used to eliminate irrelevant variables and to reveal the optimal model with a low number of parameters. The first stepwise regression included the variables T_{gen}, PR and PEOU with T_{AAL} as a dependent variable. In contrast to Steinke et al. (2014b), the variable PU was excluded, due to its missing impact on T_{AAL}, in the current study. PR ($\beta = .37$, $p < .05$) and PEOU ($\beta = .42$, $p < .01$) had a significant impact on T_{AAL}. Together, the amount of variance explained was 72% ($R^2 = .72$) (see Table 2). The results give reason to presume PR as a mediator for the relation between T_{gen} and T_{AAL}. A further analysis for mediation significance, by, for example, an application of bootstrap methods or the Sobel test, was neglected due to the small sample size. Performing the same stepwise regression to the junior sample partially supports this result. PR ($\beta = .52$, $p < .01$) also has a significant impact on T_{AAL} in this sub-sample and seems to mediate the role of T_{gen}.

Moreover, a further analysis with PEOU, T_{AAL}, PU and PR on the one side, and setting IU as a dependent variable on the other side, was performed to estimate the amount of explained variance in IU. PR had a significant impact on IU ($\beta = .83$, $p < .01$; $R^2 = .64$) when considering all variables together in an ANOVA. As a consequence, a stepwise regression to prove for mediation hints was conducted. The outcome indicates multiple mediations – as can be seen from Table 4. Thus, the data gives rise to the

assumption that PR mediates the relation between PEOU, T_{AAL}, PU and IU. Applying the analogous stepwise regression to the junior sample does not lead to contradictory results. However, the main indicator for IU is PU ($\beta = .78$, $p < .01$) in this sub-sample.

Table 3 Linear regression on T_{AAL} for the senior sample

		B	*SE*	*T*	*p*	R^2
1	Constant	1.19	.99	1.20	.24	.43
	T_{gen}	.79**	.17	4.55	.00	
2	Constant	–.01	.89	–.02	.99	.62
	T_{gen}	.23	.21	1.07	.29	
	PR	.76**	.21	3.66	.00	
3	Constant	–.86	.81	–1.06	.30	.72
	T_{gen}	.24	.18	1.30	.21	
	PR	.44*	.21	2.17	.04	
	PEOU	.45**	.14	3.19	.00	

Notes: Dependent variable = T_{AAL}. Stepwise regression.
*p < .05, **p < .01

Table 4 Linear regression on IU for the senior sample

		B	*SE*	*T*	*p*	R^2
1	Constant	1.36	1.49	.91	.369	.24
	PEOU	.75*	.25	2.99	.006	
2	Constant	.58	1.43	.41	.407	.36
	PEOU	.17	.35	.50	.621	
	T_{AAL}	.73*	.32	2.27	.031	
3	Constant	–1.14	1.33	–.86	.399	.55
	PEOU	.40	.30	1.30	.205	
	T_{AAL}	.02	.35	.06	.956	
	PU	.81*	.24	3.28	.003	
4	Constant	–2.39	1.18	–2.02	.054	.69
	PEOU	.08	.27	.28	.785	
	T_{AAL}	–.21	.30	–.69	.496	
	PU	.14	.29	.48	.639	
	PR	.1.41*	.41	3.42	.002	

Notes: Dependent variable = T_{AAL}. Stepwise regression.
*p < .05, **p < .01

To identify significant differences compared to the control group, additional analyses for the overall sample were conducted. No significant deviations regarding T_{gen} and T_{AAL} in the senior cohort ($t(58) = –1.14$, $p = .26$; $t(58) = –.88$, $p = .38$) could be found. However, there was a significant difference between junior and senior groups regarding PR of the applied mock-up following the experimental manipulation ($t(58) = –2.41$, $p = .02$).

4 Discussion

In the following, the stated hypothesis, as well as the research question – "How do the different reliability levels of an AAL application influence end-users' trust and intention to use?" – will be discussed in detail with a particular focus on the senior sample.

With regard to the research question, the findings reveal no clear universal statement regarding trust in AAL technology and intention to use. There was no evidence for the hypotheses H1(d) and H2(c), which means that both hypotheses are not supported by the data. Participants in the 100% reliability condition do not have significantly higher trust and intention to use values in contrast to participants in the conditions with an imperfect AAL application (90% or 80%). Moreover, no significant findings between the 90% and 80% reliability treatments regarding T_{AAL} and IU could be found. These results contradict findings in which participants rely more on systems with higher reliability – for example, in the context of a military command and control task (Rovira et al., 2007) or flight and display monitoring tasks (Bailey and Scerbo, 2007). Thus it should be questioned if reliability of an AAL system does not matter at all for the end-user?

Despite missing significant results from the present study, this provocative question is negated by the authors. In the context of AAL technology, which served the security of people's health, reliability plays a major role since AAL works autonomously, and far-reaching manual operation is not intended. Moreover, Steinke et al. (2013) revealed that end-users expect higher reliability values for AAL in contrast to other everyday technologies, which supports the importance reliability in context of AAL for the end-user. The missing significance regarding the connection between reliability level and T_{AAL}, as well as IU, can be interpreted in multiple ways.

One further explanation can be that the manipulation of the reliability was indistinguishable for the participants so that the application was not perceived as defective. This is in line with the mean values of perceived reliability among the different experimental groups, which did not differ significantly. Within the present experiment, the participants received no information about the reliability level of the AAL application beforehand (cf. Ezer et al., 2008) but were given feedback about errors during the experiment (cf. Rice and Geels, 2010). Rice and Geels (2010) analysed three different information/feedback scenarios and strengthened the system-wide trust strategy (Keller and Rice, 2010) in which operators do not differentiate between individual diagnostic aids with various reliability levels but perceive them as one system with consistent reliability.

Furthermore, no certain threshold of reliability below which trust declines significantly can be seen for AAL technology (cf. Lee and See, 2004). In contrast to the present experiment with AAL technology in the home environment, in other areas, such as aviation or combat identification, manipulated reliability was often tested from 100% reliability up to 70% or less (Keller and Rice, 2010; Neyedli et al., 2010; Rovira et al., 2007). Supported by Steinke et al. (2013), a reliability level of 70% or less for AAL technology would be very low in the expectation of the end-user. A reliability threshold which is significantly influencing trust in AAL should be expected above these values analysed in other automation.

The present results suggest, that in case older people have high values of PEOU and PR, these variables could overcompensate the error messages in the 80% and 90% reliability conditions and, thus, the imperfect AAL technology. Moreover, the error

messages could be perceived as additional support to the older people in order to avoid further handling errors. Thus, the manipulation of reliability in the imperfect AAL application settings could lead to a positive reinforcement of perceived reliability for older participants. The small sample size in each of the three reliability conditions could prevent significant results in regard to the differences relating to T_{AAL} and IU.

Moreover, the study reveals new insights by combining the variables PEOU, PU and IU from TAM in an experimental setting with a total of 60 people. Despite the fact that a broader sample would be necessary to calculate structural equation models, the linear regressions – as also analysed in Steinke et al. (2014b) – underlined most of the previous results. The positive influence of PEOU and PR on T_{AAL}, as well as the non-significance of PU on T_{AAL}, cover the previous results. Thus, the hypotheses H1(f) and H1(g) can be supported, and H1(h) cannot be supported by the data.

Additionally, T_{AAL}, PR, PEOU and PU have a positive influence on IU (H2(d), H2(e), H2(f) and H2(g) can be verified). The data supports the assumption that PR mediates the relation between the other former-named variables and IU. With respect to the relation between the behavioural data measured during the experiment and T_{AAL} and IU, no statistically significant results can be found. The hypotheses H1(a), H1(b), and H1(c), as well as H2(a) and H2(b), cannot be supported by the data. Table 5 gives an overview of the results of the hypotheses for the senior sample.

Table 5 Overview of support of hypotheses for the senior sample

Hypothesis		*Support*
	Trust in AAL technology (T_{AAL})	
H1(a)	Is negatively influenced by the number of clicks	No
H1(b)	Is negatively influenced by the investment of time	No
H1(c)	Is negatively influence by the number of checking operations	No
H1(d)	Is positively influenced by higher reliability level	No
H1(e)	Is positively influenced by general trust in technology (T_{gen})	Yes
H1(f)	Is positively influenced by perceived reliability (PR)	Yes
H1(g)	Is positively influenced by perceived ease of use (PEOU)	Yes
H1(h)	Is positively influenced by perceived usefulness (PU)	No
	Intention to use (IU)	
H2(a)	Is negatively influenced by the number of clicks	No
H2(b)	Is negatively influence by the investment of time	No
H2(c)	Is positively influenced by higher reliability level	No
H2(d)	Is positively influenced by trust in AAL technology (T_{AAL})	Yes
H2(e)	Is positively influenced by perceived reliability (PR)	Yes
H2(f)	Is positively influenced by perceived ease of use (PEOU)	Yes
H2(g)	Is positively influenced by perceived usefulness (PU)	Yes

Regarding the investment of time for the experimental tasks, it can be seen that elderly people needed more time to finish the experiment in all reliability conditions. Furthermore, the investment of time is negatively related to the reliability level in the senior group. These findings are correlated with the number of clicks participants needed to finish the experiment. This analysis revealed that younger people needed less clicks,

on average, than the older participants in order to finish all tasks. Something that is noteworthy in this context is the wide difference between the senior and control groups in the 80% reliability condition. Whereas older people needed more clicks and time to finish the tasks in this condition, which is in accordance with the other two conditions, the younger participants needed less clicks and time, on average, in the 80% condition. This effect should be investigated in further experiments with a broader sample.

With respect to the checking operation which was implemented to give participants the opportunity to check the system's reliability via mathematical calculations, younger participants used that function a total of 89 times – more often than the older participants with 70 times. Apparently, the participants checked the system's reliability in the first room – the hall – most frequently, although there were fewer tasks to perform and no error messages occurred in none of the experimental conditions. Moreover, the checking behaviour was not significantly influenced by the type of technical device which was operated. For example, a forgotten running stove in the kitchen has not been proven significantly more often in contrast to an open blind. In both age groups, participants in the 90% experimental condition showed the highest usage of the checking operation. In the senior sample, under the 100% reliability condition, only six people who used the checking operation were measured. Originally, this was the expected outcome and showed that higher reliability of an AAL system could lead to less manual checking by the end-user. This supports the note that high reliability of an AAL system would be necessary for the usage of AAL technology in everyday life, since this technology will work autonomously, and far-reaching manual operation is not intended, for example, in critical AAL solutions such as fall monitoring via ground sensors. Especially in the case of impaired people, the automation has to react without human support. This challenge for AAL goes beyond other human-automation systems in which a human operator acted as a safeguard.

Additionally, the present study has some limitations that should be highlighted. First, the used application is designed for the experimental setting only and is not part of an integrated system. By using a marketable product with interfaces to other technical devices, a follow-up experiment would be useful.

Second, the used reliability levels up to 80% could not contain the complete spectrum of perceived reliability by the participants. Nevertheless, due to high criticality in case of an emergency, an AAL technology with less than 80% reliability appears unanalytical. Moreover, the findings from Steinke et al. (2013) support the set border for reliability of the AAL application. Since, in former studies, reliability levels around 70% to 75% represent a threshold of performance decline (Wickens and Dixon, 2005), analysing applications with less than 80% reliability could bring new knowledge regarding the measured variables, although this will (hopefully) not be a realistic border for actual reliability of an AAL technology.

Third, the error message itself could have further influenced the results. During the experiment, some participants mentioned that they had caused the displayed errors themselves due to incorrect usage of the system. In this context, the implementation of false alarms as an additional type of error message, or more information about the reliability level for the participants in the run-up to the experiment, could reveal further interesting insights. Fourth, the sample size with ten participants per reliability level should be increased in further studies; the statistical analyses can be strengthened and the results underlined. A further limitation of the present study can be seen in the high computer usage of participants aged 70 years or above. According to the German Federal

Statistical Office (Destatis, 2013), the computer ownership by older participants in the experimental group corresponds to the comparison group (up to 70 years), whereas it is to be considered, for the group of participants older than 70 years, as above-average.

Furthermore, suggestions for further research should be mentioned. First of all, in the context of AAL technology, no previous studies with manipulation of reliability exist. Since the results are not obvious, this fact supports the idea of further research in this area. In general, fewer studies with older people as a participant group, regarding reliability and trust, exist. Thus, a follow-up study with a wider sample should be used as well as a differentiation between the type of information and feedback in terms of errors (cf. Dzindolet et al., 2003; Rice and Geels, 2010).

Since participants undertook only one reliability level each during this study, there was no direct comparison possible. Due to this fact, the experiment was repeated with an additional ten older participants (mean age = 72.0, SD = 5.27) who completed the experimental procedure twice. In contrast, in this small follow-up experiment, each participant performed the study with two different manipulated reliability levels – 80% followed by 100%, or the other way round. This additional experiment revealed a reduction in the investment of time and the number of clicks in the second experimental round independent of the sequence of the reliability conditions. Regarding the checking operations, it should be noted that, within the first sub-group (change of technical reliability from 100% to 80%), only one participant tried the control option once, while in the second subgroup (change of technical reliability from 80% to 100%), in total 49 checking operations were performed by the participants. Something that is noteworthy is the reduction of checking operations by 86.1% from the first experimental round (n = 43) to the second round (n = 6). This reflects the fact that training sessions prior to the purchase of an AAL system may lead to easier handling for older people and better support for the actual usage of the system. Due to the small sample size, no further analysis showed significant results, but this should be extended in further studies.

Moreover, the experiment did not analyse trust in highly critical AAL functions such as ‘fall monitoring’, which could be examined in a long-term study in a residential environment. For this, it would be necessary to use an AAL technology which is market ready and not only at a prototype stage. The diversity of AAL applications – for example, an alarm function with an automatic emergency call – cannot currently be mapped experimentally but should be integrated into further field experiments.

Older people will need support in using AAL applications, and this needs to be considered by the service provider. Moreover, various personal reasons, which are not analysed separately in this article, can have an influence on the measured variables. Conscientiousness, as one dimension of personality accompanied by the Big Five personality traits (Goldberg, 1990), could be, for example, a factor for checking behaviour. An additional examination of personality traits could provide more detailed conclusions in further experiments.

5 Conclusions

The present study revealed that the perceived reliability of the experimental and control groups has significant impact on trust in AAL technology. Moreover, no significant correlation between the different reliability levels in the experiment and the variables of end-user trust in AAL technology and intention to use can be found. This leads to the

conclusion that the manipulation of the AAL application in the experiment into different reliability levels did not lead automatically to a linear change in the reliability perception of the participants in context of AAL. The significant impact of perceived ease of use on trust in AAL in the present study goes along with the results from previous studies (Steinke et al., 2014a, 2014b). Further significant results revealed that the younger participants performed less additional clicks and, moreover, younger participants are significantly faster in solving the experimental tasks than the senior experimental group.

Finally, the variables of perceived ease of use, trust in AAL, as well as perceived usefulness, significantly influence intention to use in the senior sample, mediated by perceived reliability. In the junior group, the main indicator for intention to use was perceived usefulness. The connection between perceived usefulness and intention to use is consistent with previous findings in the context of AAL (Steinke et al., 2014b).

References

Abe, G. and Richardson, J. (2006) 'Alarm timing, trust and driver expectation for forward collision warning systems', *Applied Ergonomics*, Vol. 37, No. 5, pp.577–586.

Afentakis, A. and Maier, T. (2010) 'Projektionen des Personalbedarfs und -angebots in Pflegeberufen bis 2025', *Statistisches Bundesamt, Wirtschaft und Statistik*, Vol. 11, pp.990–1002.

Ambient Assisted Living Joint Programme (2013) *Catalogue of Projects 2013* [online] http://www.aal-europe.eu/wpcontent/uploads/2013/09/AALCatalogue2013_Final.pdf (accessed 28 October 2013).

Bailey, N.R. and Scerbo, M.W. (2007) 'Automation-induced complacency for monitoring highly reliable systems: the role of task complexity, system experience, and operator trust', *Theoretical Issues in Ergonomics Science*, Vol. 8, No. 4, pp.321–348.

Belbachir, A.N., Litzenberger, M., Schraml, S., Hofstatter, M., Bauer, D., Schon, P. and Merne, M. (2012) *Proceedings from IEEE International Symposium on Circuits and Systems – ISCAS 2012*, Institute of Electrical and Electronics Engineers, Seoul, Circuits and Systems Society.

BITKOM (2009) *60 Prozent der Deutschen über 65 Jahre wollen Telemedizin nutzen*, BITKOM [online] http://www.bitkom.org/de/presse/62013_59050.aspx (accessed 22 July 2014).

Bliss, J.P. and Dunn, M.C. (2000) 'Behavioural implications of alarm mistrust as a function of task workload', *Ergonomics*, Vol. 43, No. 9, pp.1283–1300.

Davis, F.D. (1989) 'Perceived usefulness, perceived ease of use, and user acceptance of information technology', *MIS Quarterly*, Vol. 13, No. 3, pp.319–340.

Destatis (Statistisches Bundesamt) (2011) *Im Blickpunkt: Ältere Menschen in Deutschland und der EU*, Destatis [online] https://www.destatis.de/DE/Publikationen/Thematisch/Bevoelkerung/Bevoelkerungsstand/BlickpunktAeltereMenschen1021221119004.pdf?__blob=publicationFile (accessed 14 April 2014).

Destatis (Statistisches Bundesamt) (2013) 'Wirtschaftsrechnungen – Laufende Wirtschaftsrechnungen: Ausstattung privater Haushalte mit ausgewählten Gebrauchsgütern 2012', *Fachserie*, Vol. 15, No. 2 [online] https://www.destatis.de/DE/Publikationen/Thematisch/EinkommenKonsumLebensbedingungen/LfdWirtschaftsrechnungen/AusstattungprivaterHaushalte2150200127004.pdf?__blob=publicationFile (accessed 14 April 2014).

Dixon, S.R. and Wickens, C.D. (2006) 'Automation reliability in unmanned aerial vehicle control: a reliance-compliance model of automation dependence in high workload', *Human Factors*, Vol. 48, No. 3, pp.474–486.

Dzindolet, M.T., Beck, H.P., Pierce, L.G. and Dawe, L.A. (2001) *A Framework of Automation Use*, Report No. ARL-TR-2412, Army Research Laboratory, Aberdeen Proving Ground, MD.

Dzindolet, M.T., Peterson, S.A., Pomranky, R.A. Pierce, L.G. and Beck, H.P. (2003) 'The role of trust in automation reliance', *International Journal of Computer Studies*, Vol. 58, No. 6, pp.697–718.

Dzindolet, M.T., Pierce, L.G., Beck, H.P. and Dawe, L.A. (2002) 'The perceived utility of human and automated aids in a visual detection task', *Human Factors*, Vol. 44, No. 1, pp.79–94.

Elder-Spaces (2011) *Managing Older People Social Relationships for better Communication, Activation and Interaction*, Elder Spaces [online] http://www.elderspaces.eu/ (accessed 22 July 2014).

Elsayed, A. (2012) *Reliability Engineering*, Wiley Series in Systems Engineering and Management, 2nd ed., John Wiley & Sons, New Jersey.

European Ambient Assisted Living Innovation Alliance (AALIANCE) (2010) *Ambient Assisted Living Roadmap – Ambient Intelligence and Smart Environments*, Non Basic Stock Line, Doncaster.

Ezer, N., Fisk, A.D. and Rogers, W.A. (2008) 'Age-related differences in reliance behavior attributable to costs within a human-decision aid system', *Human Factors*, Vol. 50, No. 6, pp.853–863.

Floeck, M. and Litz, L. (2008) 'Integration of home automation technology into an assisted living concept', *Assisted Living Systems – Models, Architectures and Engineering Approaches* [online] http://drops.dagstuhl.de/opus/volltexte/2008/1459/pdf/07462.FloeckMartin.Paper.1459.pdf (accessed 22 July 2014).

Fraunhofer ISST (2013) *Smart and Independent Living for the Elderly – SMILEY – Projektabschlussbericht*, Fraunhofer ISST [online] http://www.isst.fraunhofer.de/content/dam/isst/de/documents/Forschungsnews/Fraunhofer-ISST_SMILEYSchlussbericht_1.1.pdf (accessed 14 April 2013).

Goldberg, L.R. (1990) 'An alternative 'description of personality': the big-five factor structure', *Journal of Personality and Social Psychology*, Vol. 59, No. 6, pp.1216–1229.

Grauel, J. and Spellerberg, A. (2008) 'Wohnen mit Zukunft - Soziologische Begleitforschung zu Assisted Living-Projekten', in Maier, E. and Roux, P. (Eds.): *Seniorengerechte Schnittstellen zur Technik: Zusammenfassung der Beiträge zum Usability Day VI*, pp.36–43, Pabst Science Publ., Lengerich.

Hertzer, A. (2013) *Zuverlässigkeit als Einflussfaktor für Vertrauen älterer Personen in häusliche Unterstützungstechnologien*, Universität Augsburg, Professur für Wirtschaftsinformatik und Management Support, Augsburg.

Ho, G., Wheatley, D. and Scialfa, C.T. (2005) 'Age differences in trust and reliance of a medication management system', *Interacting with Computers*, Vol. 17, No. 6, pp.690–710.

Hughes, J.S., Rice, S., Trafimow, D. and Clayton, K.D. (2009) 'The automated cockpit: a comparison of attitudes towards human and automated pilots', *Transportation Research*, Vol. 12, No. 5, pp.428–439.

Jian, J.Y., Bisantz, A.M. and Drury, C.G. (2000) 'Foundations for an empirically determined scale of trust in automated systems', *International Journal of Cognitive Ergonomics*, Vol. 4, No. 1, pp.53–71.

Kantowitz, B.H., Hanowski, R.J. and Kantowitz, S.C. (1997) 'Driver acceptance of unreliable traffic information in familiar and unfamiliar settings', *Human Factors*, Vol. 39, No. 2, pp.164–176.

Keller, A. and Rice, S. (2010) 'System-wide versus component-specific trust using multiple aids', *The Journal of General Psychology*, Vol. 137, No. 1, pp.114–128.

Lee, J.D. and Moray, N. (1992) 'Trust, control and allocation of function on human-machine systems', *Ergonomics*, Vol. 35, No. 10, pp.1243–1270.

Lee, J.D. and Moray, N. (1994) 'Trust, self-confidence and operator's adaptation to automation', *International Journal of Human Computer Studies*, Vol. 40, No. 1, pp.153–184.

Lee, J.D. and See, K.A. (2004) 'Trust in automation: designing for appropriate reliance', *Human Factors*, Vol. 46, No. 1, pp.50–80.

Lees, M.N. and Lee, J.D. (2007) 'The influence of distraction and driving context on driver response to imperfect collision warning systems', *Ergonomics*, Vol. 50, No. 8, pp.1264–1286.

Madhavan, P., Wiegmann, D.A. and Lacson, F.C. (2006) 'Automation failures on tasks easily performed by operators undermine trust in automated aids', *Human Factors*, Vol. 48, No. 2, pp.241–256.

McGuirl, J.M. and Sarter, N.B. (2006) 'Supporting trust calibration and the effective use of decision aids by presenting dynamic system confidence information', *Human Factors*, Vol. 48, No. 4, pp.656–665.

Moray, N., Inagaki, T. and Itoh, M. (2000) 'Adaptive automation, trust, and self-confidence in fault management of time-critical tasks', *Journal of Experimental Psychology*, Vol. 6, No. 1, pp.44–58.

Naresky, J.J. (1970) 'Reliability definitions', *IEEE Transactions on Reliability*, Vol. 19, No. 4, pp.198–200.

National Transportation Safety Board (1997) *Grounding of the Panamanian Passenger Ship Royal Majesty on Rose and Crown Shoal near Nantucket, Massachusetts on June 10, 1995*, NTSB [online] http://www.ntsb.gov/doclib/reports/1997/mar9701.pdf (accessed 14 April 2014).

Neyedli, H.F., Wang, L.J., Jamieson, G.A. and Hollands, J.G. (2010) 'Evaluating reliance on combat identification systems: the role of reliability feedback', in Andrews, D.H., Herz, R.P. and Wolf, M.B. (Eds.): *Human Factors Issues in Combat Identification*, pp.249–264, Ashgate, Burlington.

Parasuraman, R. and Miller, C. (2004) 'Trust and etiquette in high-criticality automated systems', *Communications of the Association for Computing Machinery*, Vol. 47, No. 4, pp.51–55.

Parasuraman, R. and Riley, V. (1997) 'Humans and automation: use, misuse, disuse, abuse', *Human Factors*, Vol. 39, No. 2, pp.230–253.

Parasuraman, R. and Wickens, C.D. (2008) 'Humans: still vital after all these years of automation', *Human Factors*, Vol. 50, No. 3, pp.511–520.

Paulus, W., Hilbert, J. and Potratz, W. (2009) 'ICT for housing', in Malanowski, N. and Cabrera, M. (Eds.): *Information and Communication Technologies for Active Ageing. Opportunities and Challenges for the European Union*, pp.205–215, Ios Pr, Amsterdam.

Rice, S. (2009) 'Examining single- and multiple-process theories of trust in automation', *The Journal of General Psychology*, Vol. 136, No. 3, pp.303–319.

Rice, S. and Geels, K. (2010) 'Using system-wide trust theory to make predictions about dependence on four diagnostic aids', *The Journal of General Psychology*, Vol. 137, No. 4, pp.362–375.

Rovira, E., McGarry, K. and Parasuraman, R. (2007) 'Effects of imperfect automation on decision making in a simulated command and control task', *Human Factors*, Vol. 49, No. 1, pp.76–87.

Stanton, N.A. and Young, M.S. (2005) 'Driver behaviour with adaptive cruise control', *Ergonomics*, Vol. 48, No. 10, pp.1294–1313.

Statistische Ämter des Bundes und der Länder (2010) *Demografischer Wandel in Deutschland, Heft 2, Auswirkungen auf Krankenhausbehandlungen und Pflegebedürftige im Bund und in den Ländern*, Wiesbaden [online] http://www.statistikportal.de/statistikportal/demografischer_wandel_heft2.pdf (accessed 11 March 2014).

Steinke, F., Fritsch, T. and Silbermann, L. (2012a) 'Trust in ambient assisted living (AAL) – a systematic review of trust in automation and assistance systems', *International Journal on Advances in Life Sciences*, Vol. 4, Nos. 3 and 4, pp.77–88.

Steinke, F., Fritsch, T., Brem, D. and Simonsen, S. (2012b) 'Requirement of AAL systems – older persons' trust in sensors and characteristics of AAL technologies', *Proceedings of the 5th ACM International Conference on Pervasive Technologies Related to Assistive Environments*, Heraklion, pp.1–6.

Steinke, F., Fritsch, T., Hertzer, A., Tautz, H. and Zickwolf, S. (2013) 'Expected reliability of everyday – and ambient assisted living technologies – results from an online survey', *International Journal of Advanced Computer Science & Applications*, Vol. 4, No. 6, pp.17–22.

Steinke, F., Bading, N., Fritsch, T. and Simonsen, S. (2014a) 'Factors influencing trust in ambient assisted living technology: a scenario-based analysis', *Gerontechnology*, Vol. 12, No. 2, pp.81–100.

Steinke, F., Ingenhoff, A. and Fritsch, T. (2014b) 'Personal remote assistance in ambient assisted living experimental research of elderly people trust and intention to use', *International Journal of Human Computer Interaction*, Vol. 30, No. 7, pp.560–574.

United Nations (2013) *World Population Policies 2011*, Department of Economic and Social Affairs, New York [online] http://www.un.org/en/development/desa/population/publications/pdf/policy/WPP2011/wpp2011.pdf (accessed 14 April 2014).

United Nations Department of Economic and Social Affairs (UNDESA) (2010) *World Population Ageing 2009*, United Nations Department of Economic and Social Affairs – Population Division [online] http://www.un.org/esa/population/publications/WPA2009/WPA2009_WorkingPaper.pdf (accessed 14 April 2014).

Verband der Elektrotechnik (VDE) (2009) *Breite Nutzung von Ambient Assisted Living bis 2015 erwartet*, news aktuell [online] http://www.presseportal.de/pm/9158/1342213/breite-nutzung-von-ambient assisted-living-bis-2015-erwartet (accessed 23 July 2014).

Wang, L., Jamieson, G.A. and Hollands, J.G. (2009) 'Trust and reliance on an automated combat identification system', *Human Factors*, Vol. 51, No. 3, pp.281–291.

Wickens, C.D. and Colcombe, A. (2007) 'Dual-task performance consequences of imperfect alerting associated with a cockpit display of traffic information', *Human Factors*, Vol. 49, No. 5, pp.839–850.

Wickens, C.D. and Dixon, S.R. (2005) *Is There a Magic Number 7 (to the Minus 1)? The Benefits of Imperfect Diagnostic Automation: A Synthesis of the Literature*, Tech. Rep. AHFD-05-01/MAAD-05-1, Savoy, IL, & University of Illinois, Aviation Human Factors Division.

Wickens, C.D., Rice, S., Keller, D., Hutchins, S., Hughes, J. and Clayton, K. (2009) 'False alerts in air traffic control conflict alerting system: is there a 'cry wolf' effect?', *Human Factors*, Vol. 51, No. 4, pp.446–462.

Wiegmann, D.A., Rich, A. and Zhang, H. (2001) 'Automated diagnostic aids: the effects of aid reliability on users' trust and reliance', *Theoretical Issues in Ergonomics Science*, Vol. 2, No. 4, pp.352–367.

Yeh, M. and Wickens, C. (2011) 'Display signaling in augmented reality: effects of cue reliability and image realism on attention allocation and trust calibration', *Human Factors*, Vol. 43, No. 3, pp.355–365.

Appendix

Overview of the 30 experimental tasks

No.	*Room*	*Device*	*Action*
1	Hall	Answering machine	Switch on
2	Hall	Light	Switch on
3	Kitchen	Window	Close
4	Kitchen	Blinds	Close
5	Kitchen	Light	Switch on
6	Kitchen	Radio	Switch on
7	Kitchen	Coffee machine	Switch off
8	Kitchen	Stove	Switch off
9	Kitchen	Oven	Switch off
10	Utility room	Window	Close
11	Utility room	Blind	Close
12	Utility room	Alarm device	Switch on
13	Utility room	Heating	Set to 19 degree
14	Living room	Window 1	Close
15	Living room	Window 2	Close
16	Living room	Blinds 1	Close
17	Living room	Blinds 2	Close
18	Living room	Light	Switch on
19	Living room	Window	Switch on
20	Bath	Window	Close
21	Bath	Blinds	Close
22	Bath	Light	Switch on
23	Bath	Washing machine	Switch on
24	Bedroom	Window	Close
25	Bedroom	Blinds	Close
26	Bedroom	Light	Switch on
27	Spare room	Windows	Close
28	Spare room	Blinds	Close
29	Spare room	Light	Switch on
30	Spare room	Radio	Switch on